21 October 2005 panoramas

Update on Validation of AIRS Radiances, Retrievals, and OLR Products

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Bob Knuteson, Leslie Moy, Lori Borg, Joe Taylor,
Steve Dutcher, and the whole Scanning HIS Team

University of Wisconsin-Madison
Space Science and Engineering Center (SSEC)

AIRS Science Team Meeting
9-12 October 2007

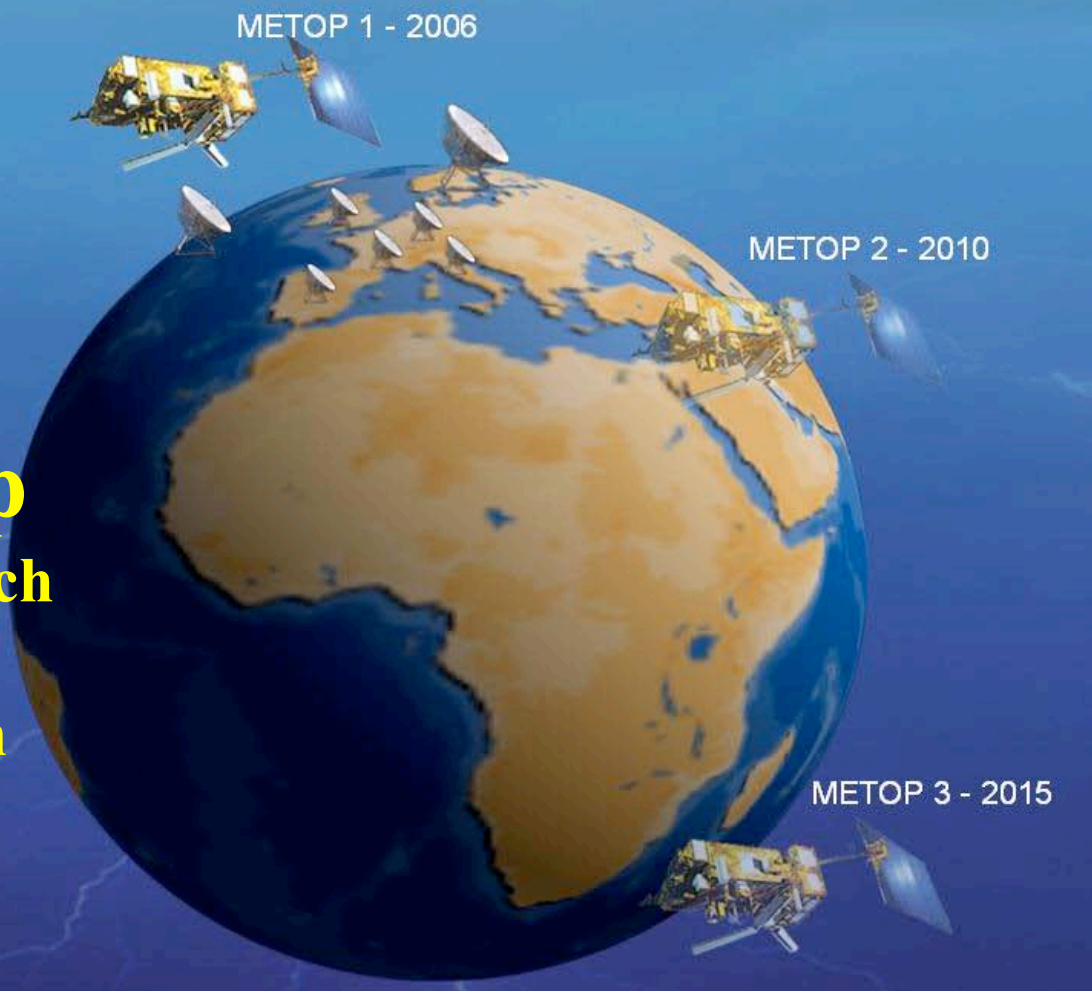
Radiance Validation

- JAIVEx: new data for IASI and AIRS
- The NIST Connection: Recent results

IASI

METOP

- Eumetsat Polar System Elements
- 14 years of operation
- >95% reliability on 5 years



IASI on Metop

19 October 2006 launch

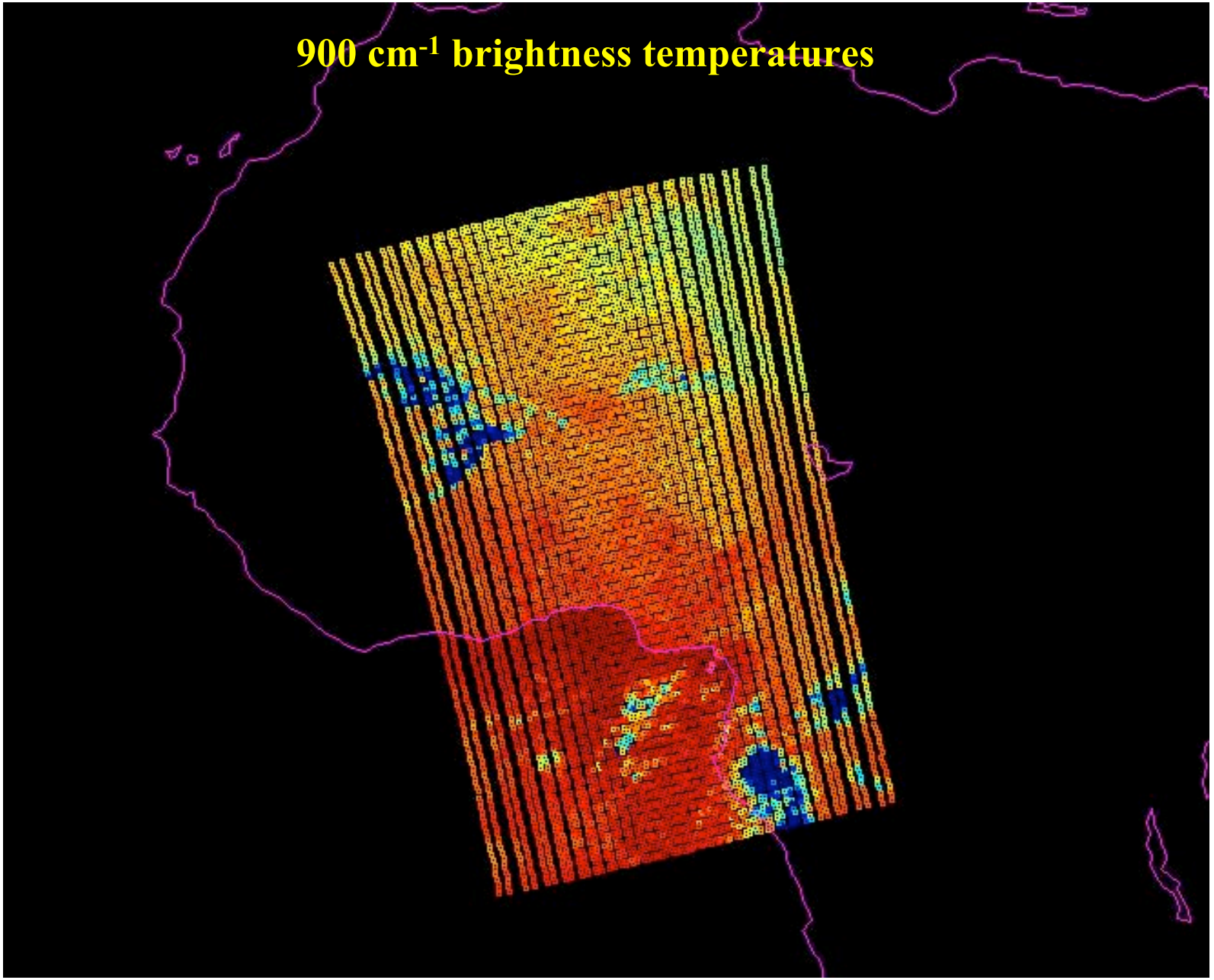
- full cross-track scan
- 2x2 12 km pixels
sample 50x50 km

EUMETSAT

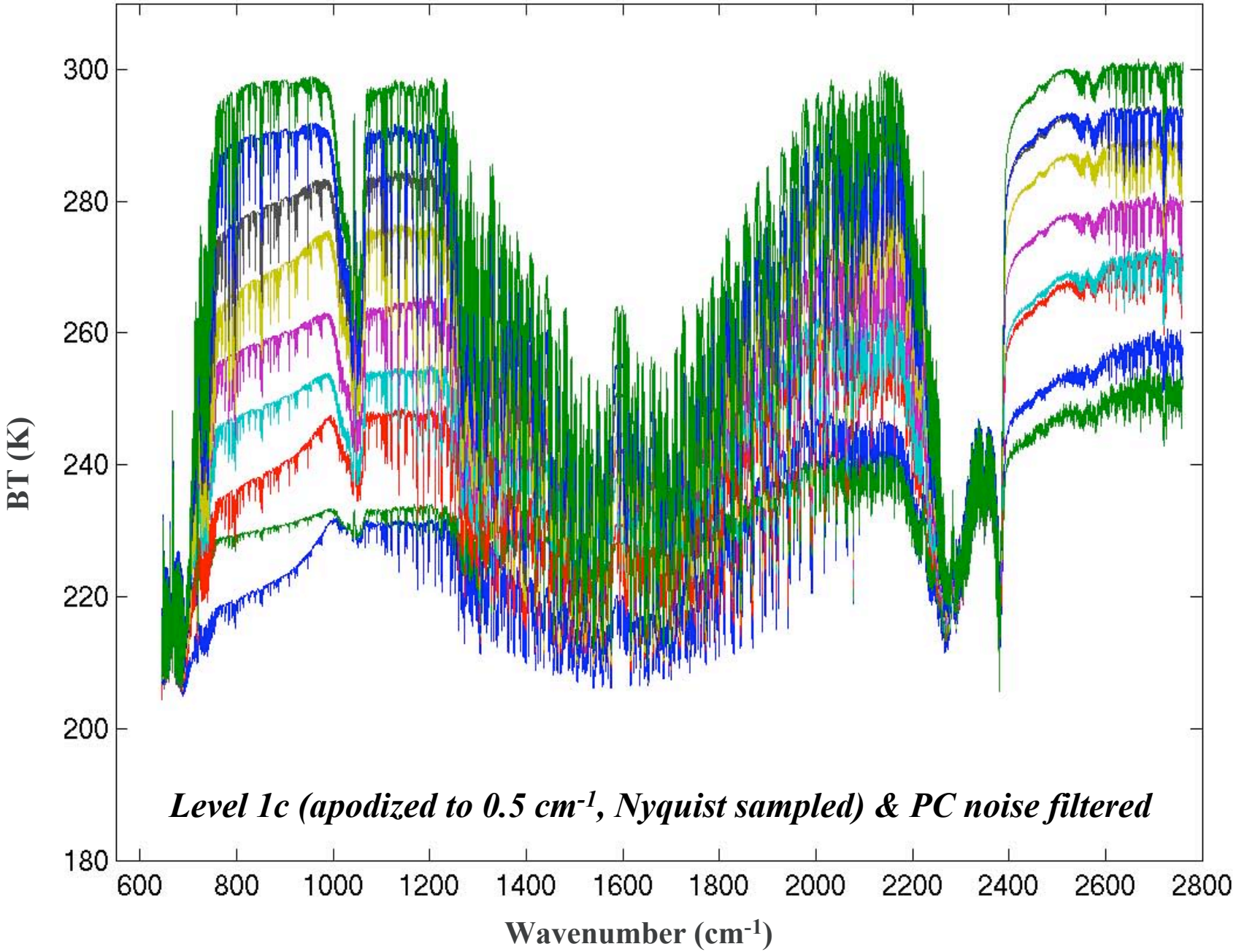
EPS QUIT

cnes

Cross-track scan pattern for 3 Sample Granules

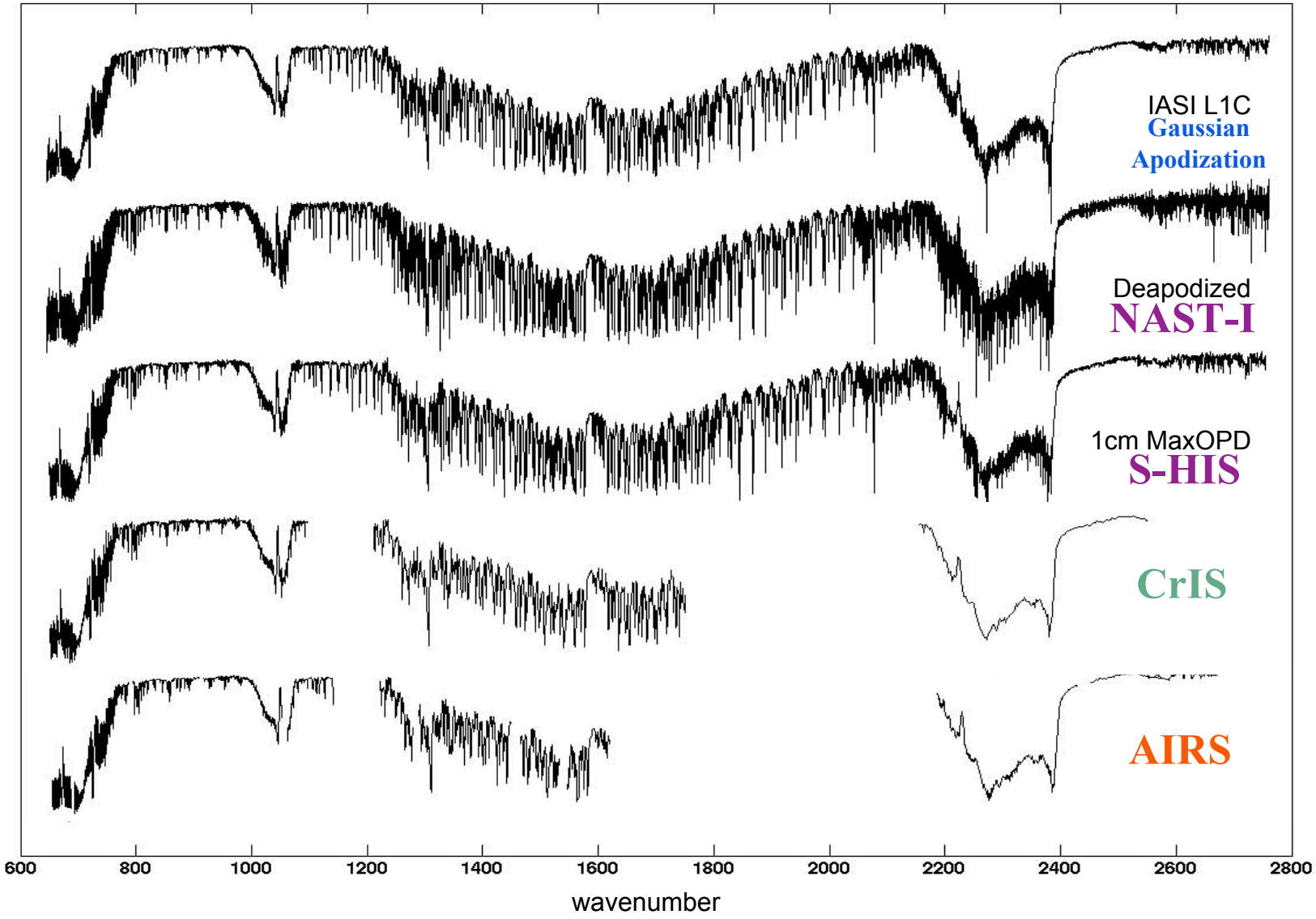


Sample IASI spectra



IASI T_b Spectrum:

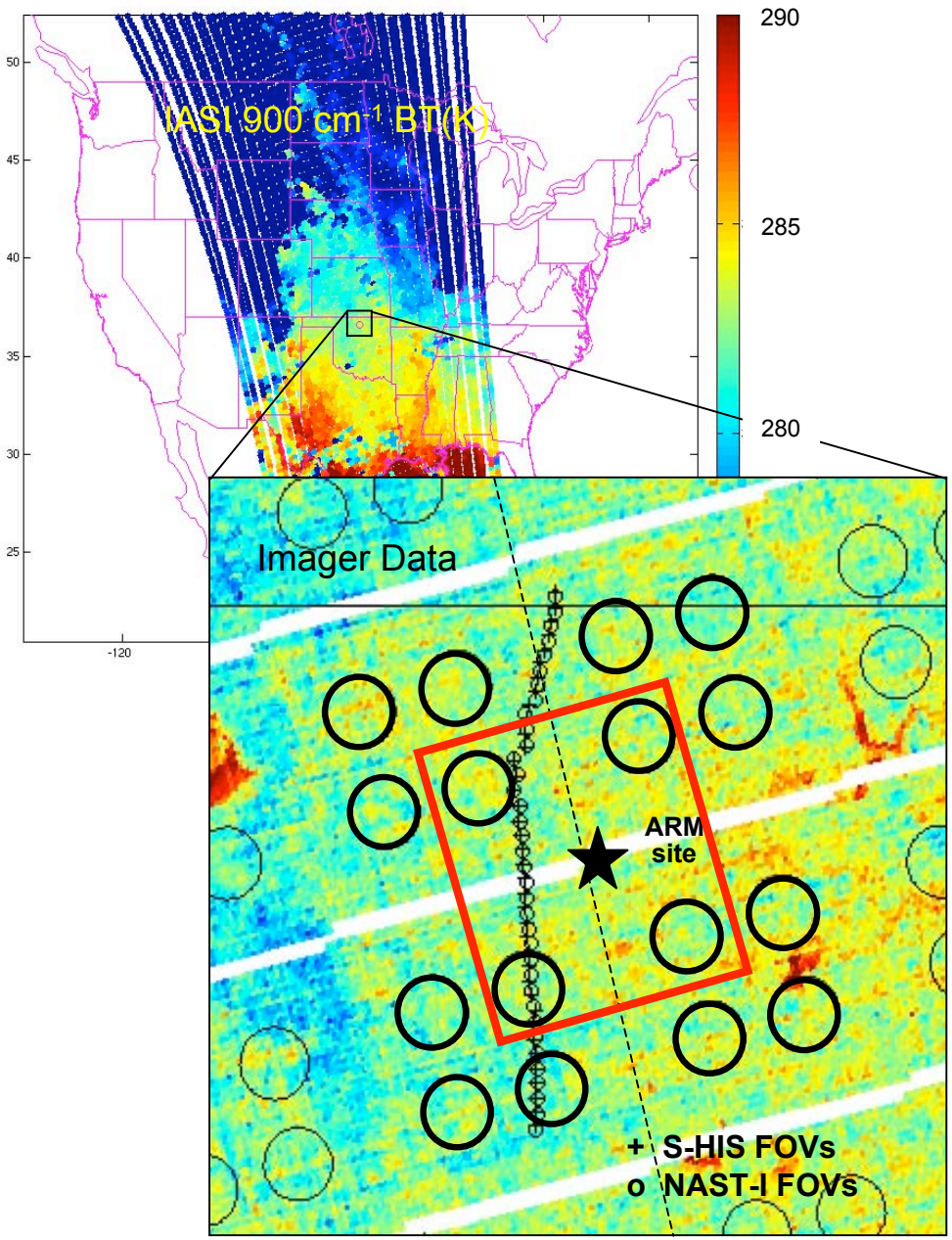
Processed to represent S-HIS & NAST-I, AIRS & CrIS

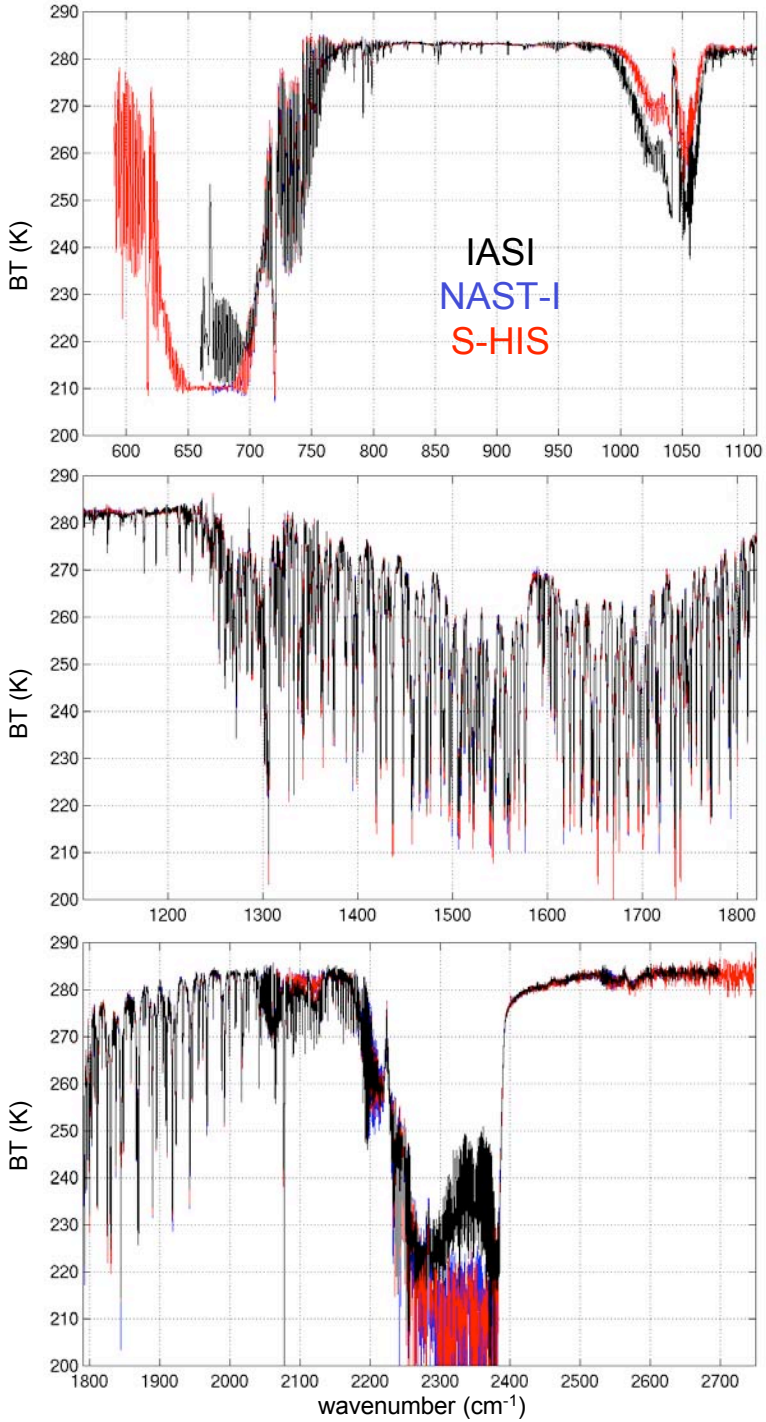


Joint Airborne IASI Validation Experiment (JAIVEx)

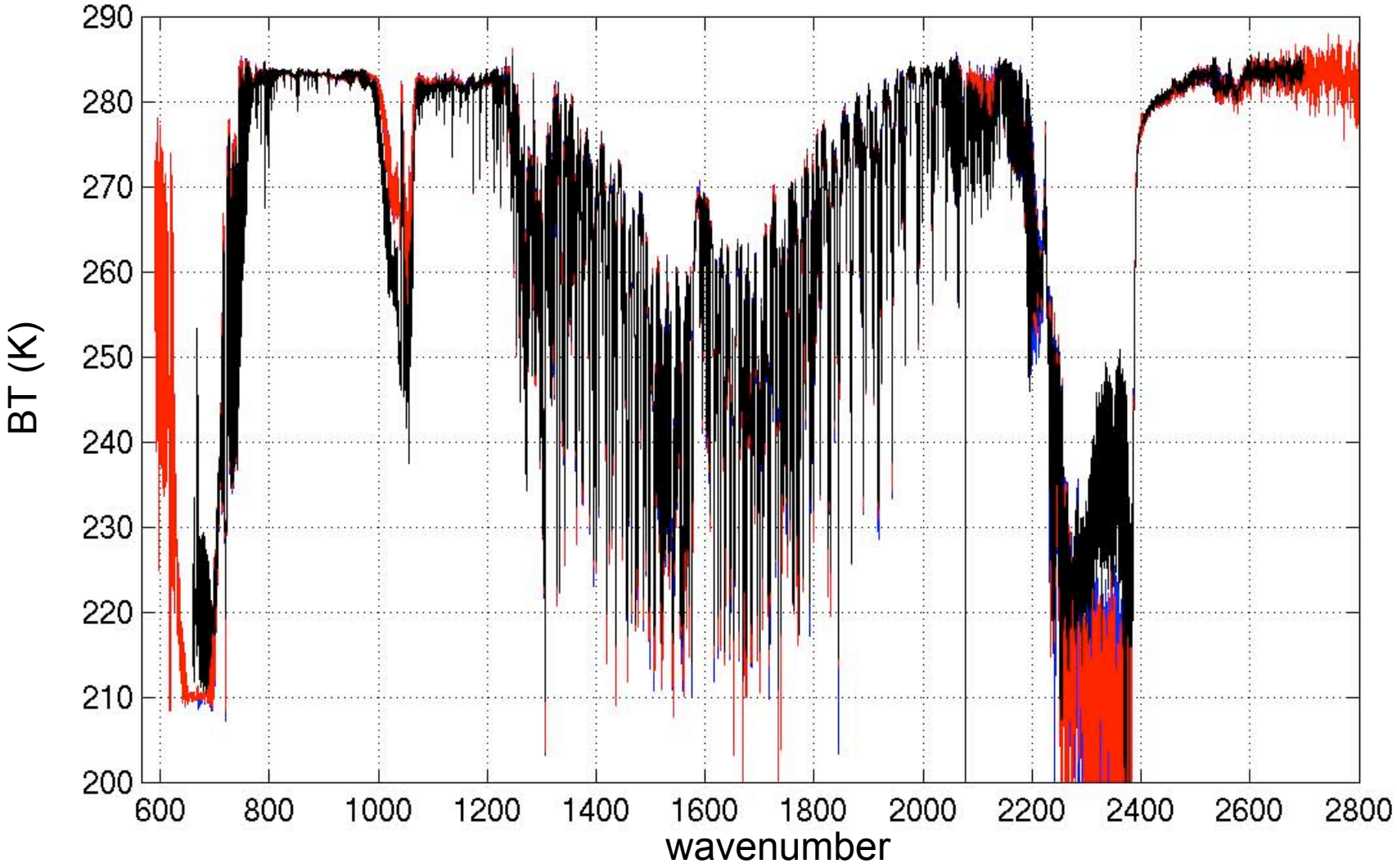
- **What:** Metop and Aqua satellite under-flights for radiance and retrieval validation (IPO/UK/EUMETSAT supported)
- **Who:** NPOESS Airborne Sounder Testbed team (NAST-I/M & S-HIS on NASA WB57) & UK team (ARIES on Facility for Airborne Atmospheric Measurements BAe146-301)
- **When:** 14 April to 4 May 2007
- **Where:** Comparisons over the Gulf and Oklahoma ARM site reached from Houston airbase

Flight over ARM SGP, 19 April 07





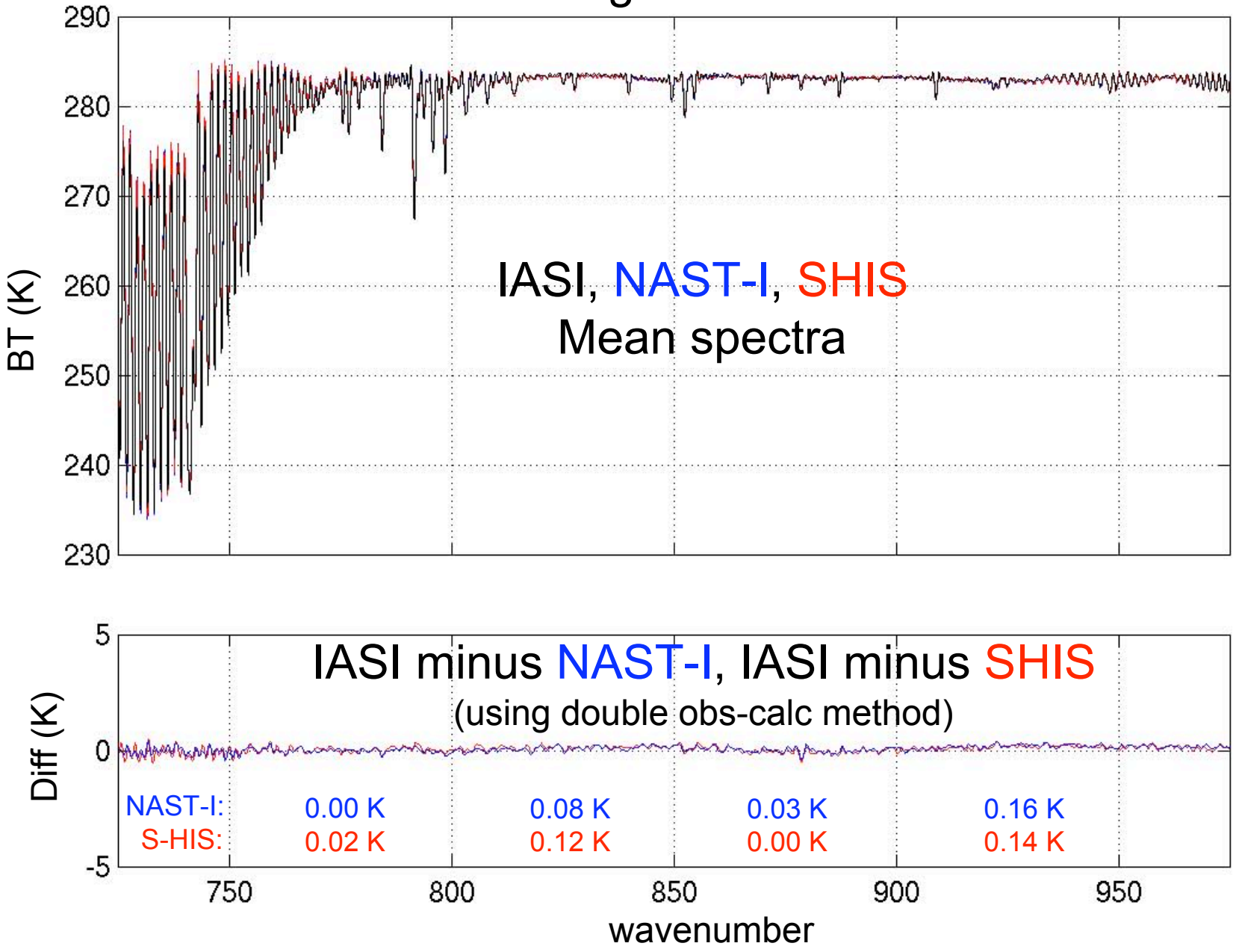
All Bands

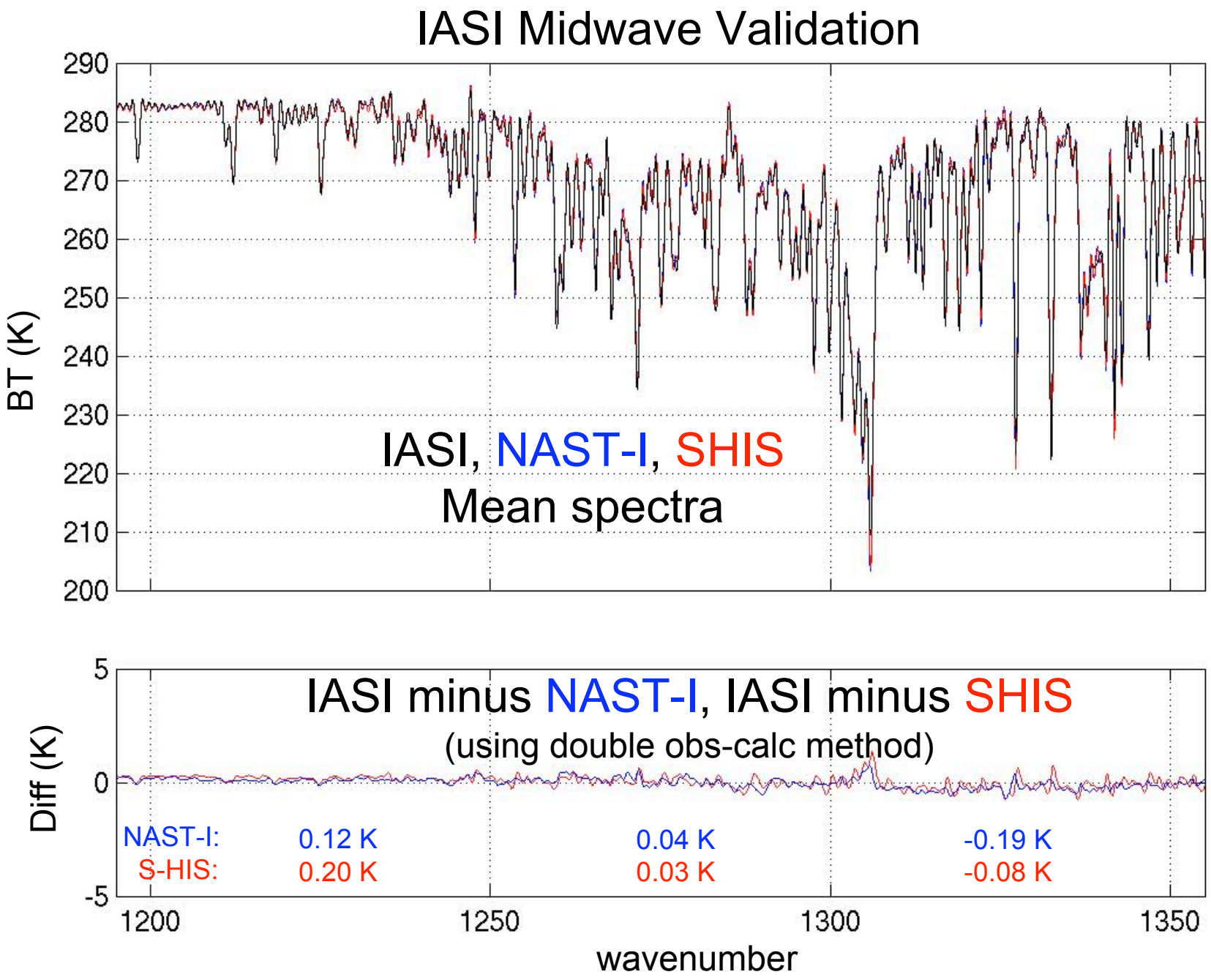


IASI, NAST-I, and SHIS Mean Spectra

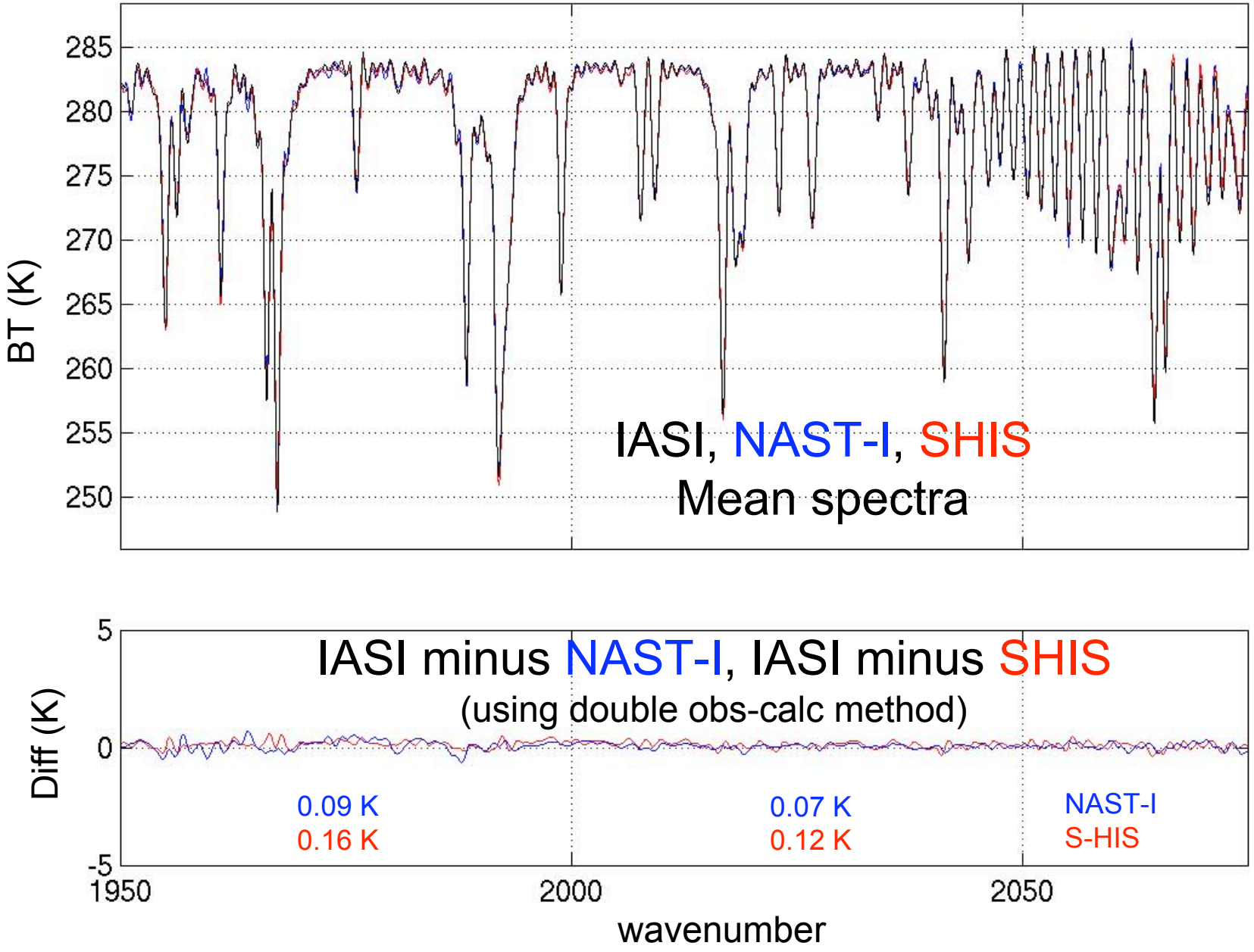
(IASI L1C and NASTI spectra processed to match SHIS spectral resolution)

IASI Longwave Validation

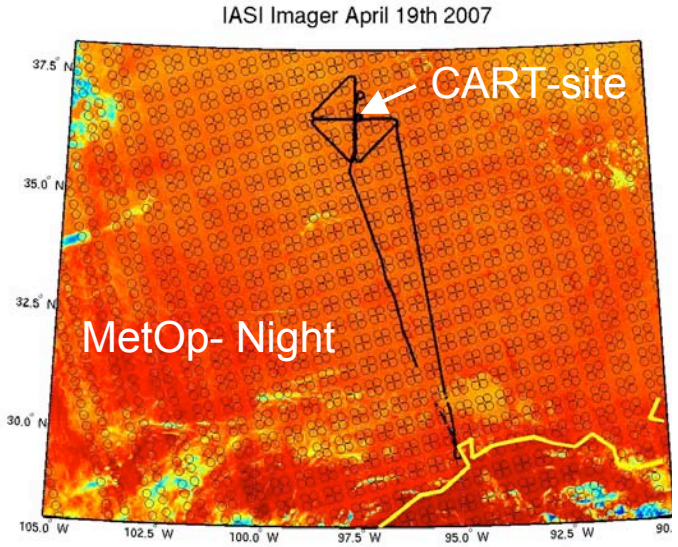


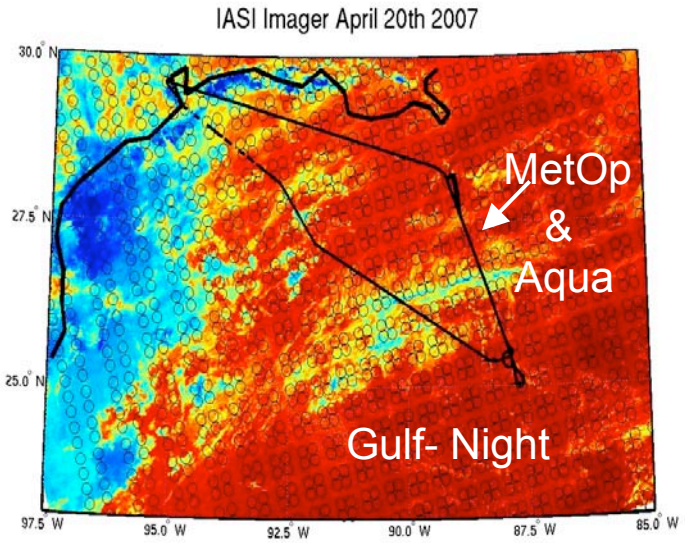

IASI Midwave Validation
BT (K)
290
280
270
260
250
240
230
220
210
200
IASI, NAST-I, SHIS
Mean spectra
Diff (K)
5
0
-5
IASI minus NAST-I, IASI minus SHIS
(using double obs-calc method)
NAST-I:
S-HIS:
0.12 K
0.20 K
0.04 K
0.03 K
-0.19 K
-0.08 K
1200
1250
1300
1350
wavenumber

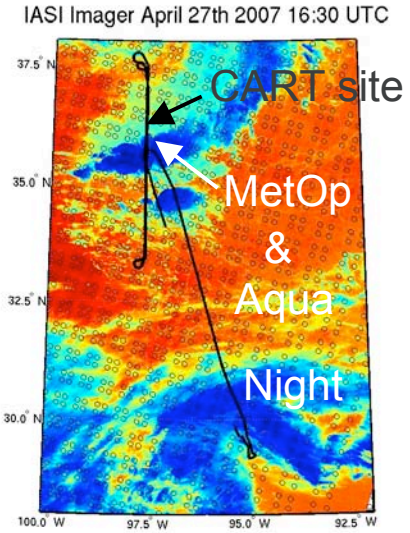
IASI Shortwave Validation

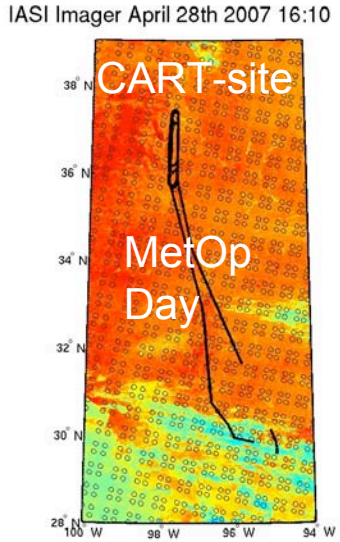


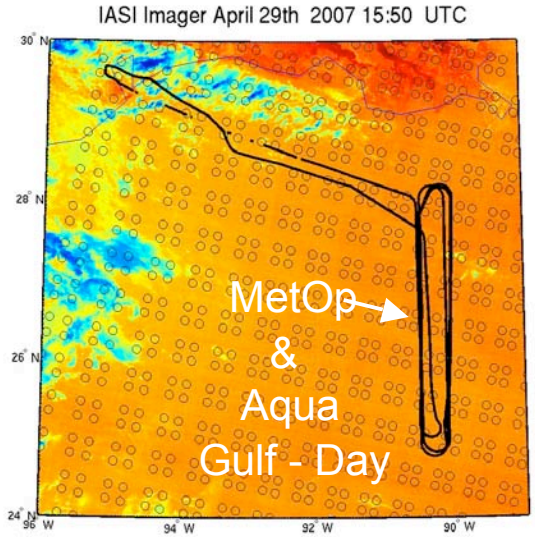
Seven JAIVEx MetOp Cal/Val Flights

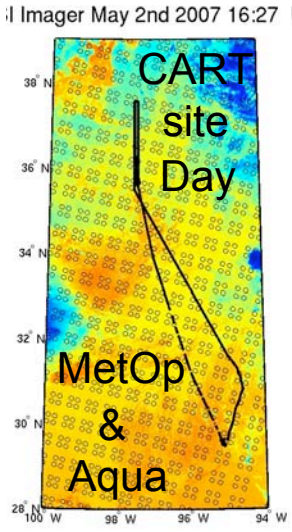


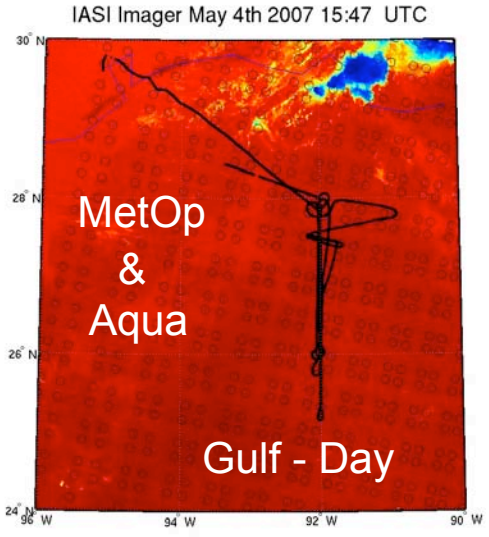












Four CART-site (2 day & 2 night); Three Gulf of Mexico (2 day & 1 night); Five joint MetOp & Aqua (3 day & 2 night)

Summary of Radiance Validation for climate

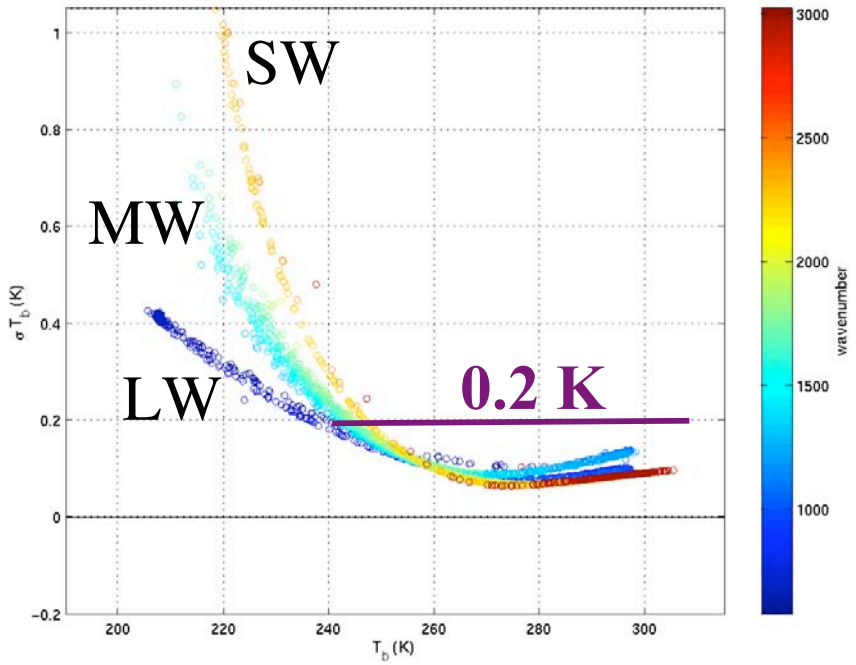
- The absolute calibration of IASI and AIRS Radiance are comparable and represent a huge improvement over past IR sounders for both weather and climate applications
- The value of aircraft observations for direct radiance validation has now been definitively proven
- Validation over their lifetime is still needed to assure the long-term stability

The NIST Connection for Scanning HIS and AIRS / IASI…

Why should you believe any of these measurements?

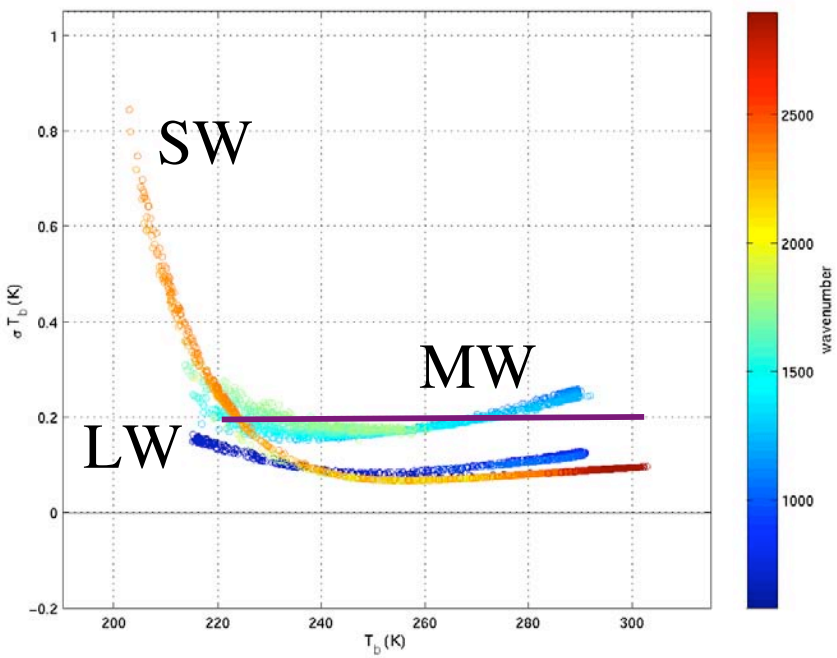
Scanning-HIS Radiometric Calibration 3-sigma Error Budget

T_{ABB} = 260K, T_{HBB} = 310K



21 November 2002
on ER2

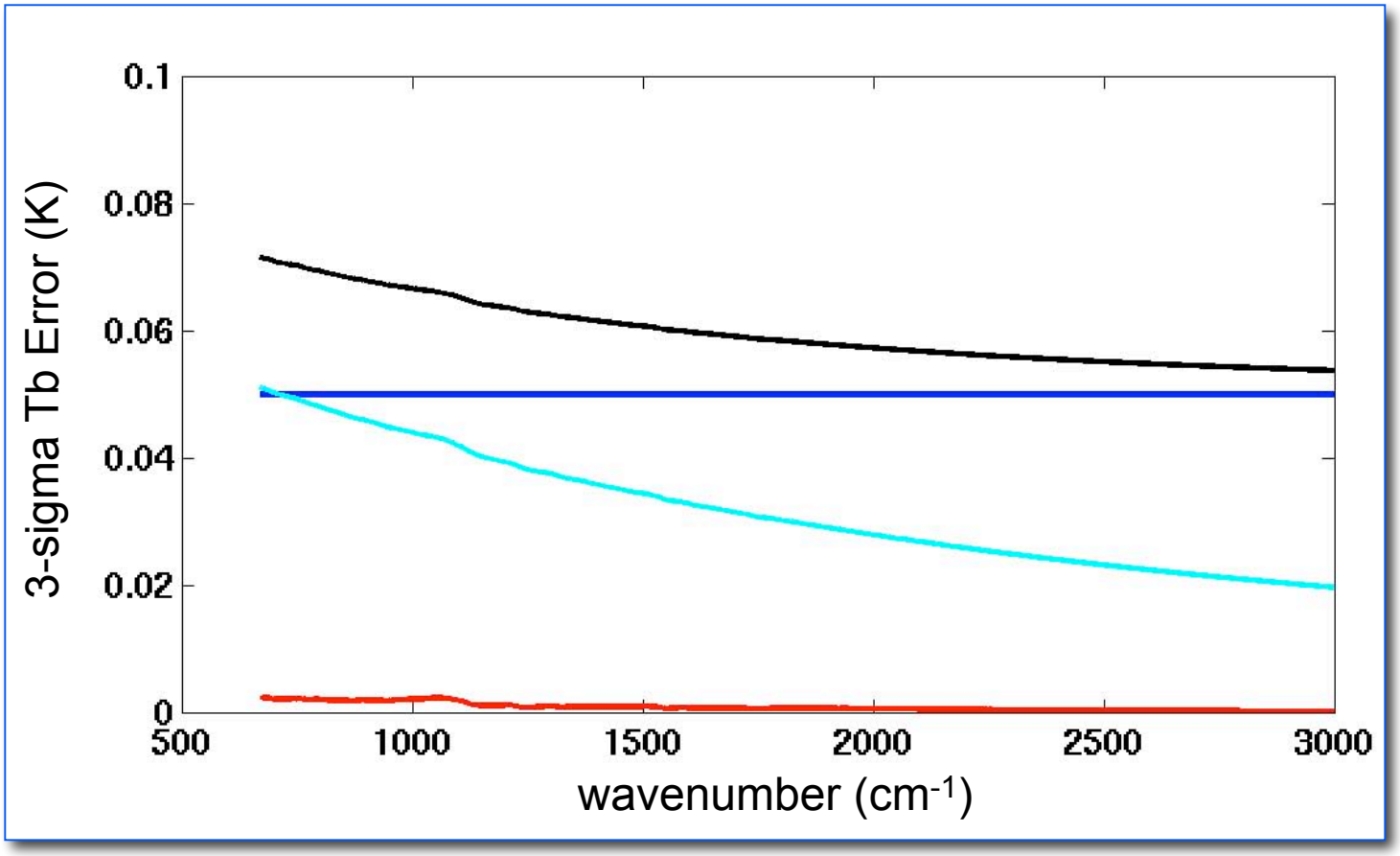
T_{ABB} = 227K, T_{HBB} = 310K



16 November 2002
on Proteus

UW-SSEC AERI Blackbody Predicted Radiance Uncertainty

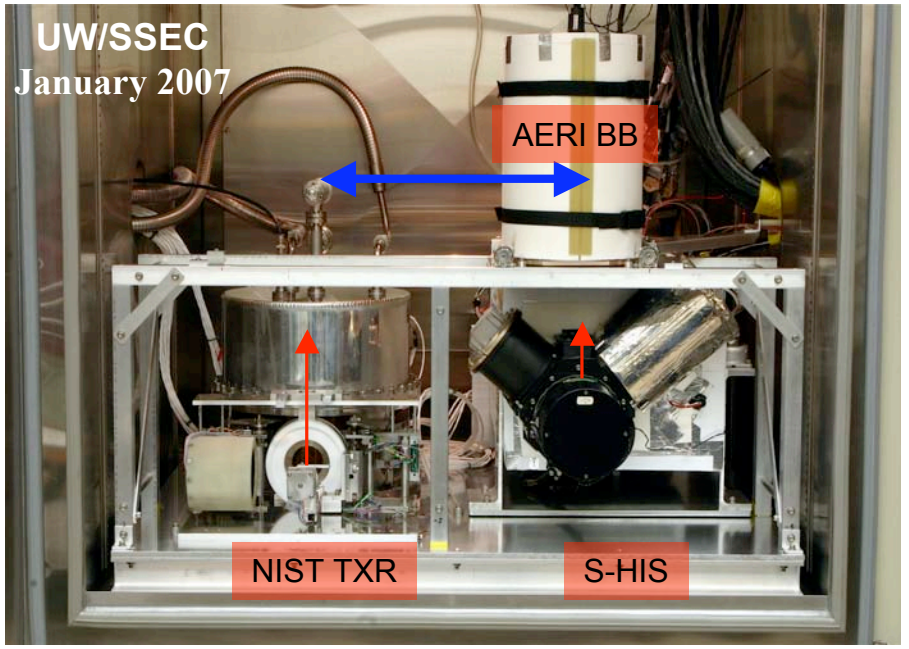
Uncertainty for T_{BB} = 293K, T_{Refl} = 230K



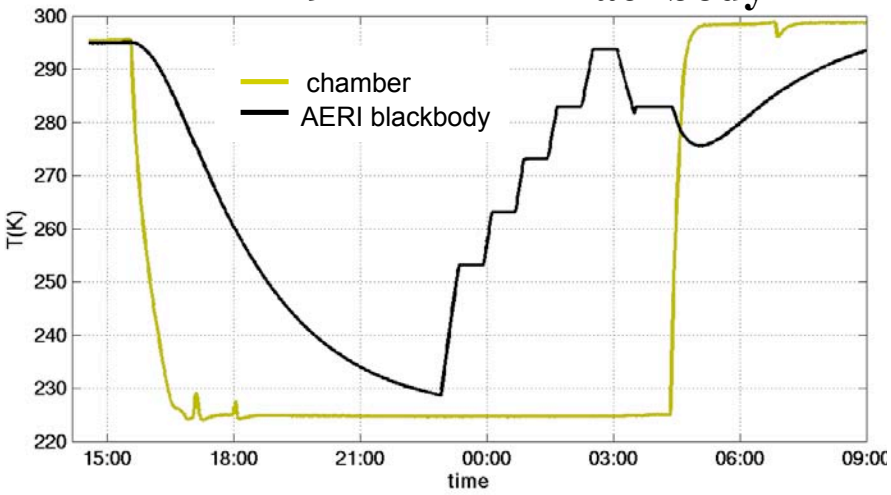
3σ Uncertainties: $3\sigma T_{BB}$ = 0.05 K $3\sigma T_{Refl}$ = 5 K $3\sigma \varepsilon_{BB}$ = 0.001 **Total (RSS)**

UW S-HIS & AERI Blackbody Absolute Accuracy: The NIST Connection for true SI Traceability

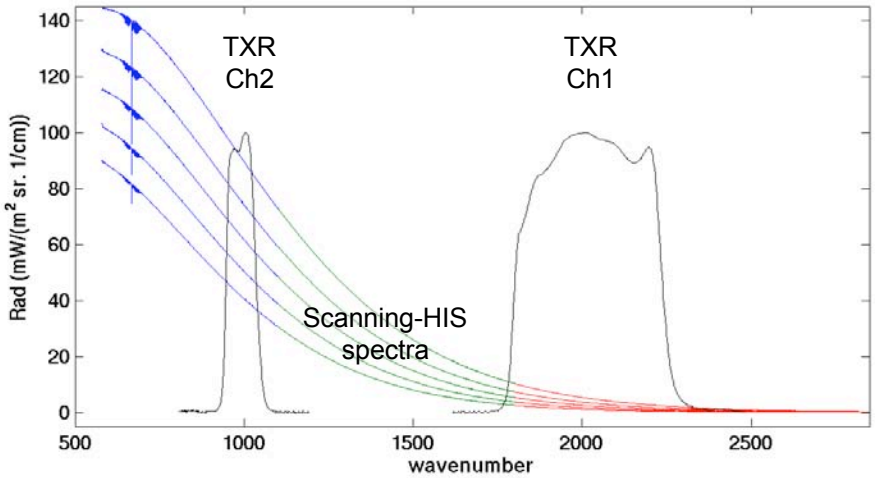
Recent end-to-end radiance evaluations conducted under S-HIS flight-like conditions with NIST transfer sensor (TXR) such that S-HIS satellite validation & AERI observations are traceable to the NIST radiance scale



227 – 294 K AERI Blackbody



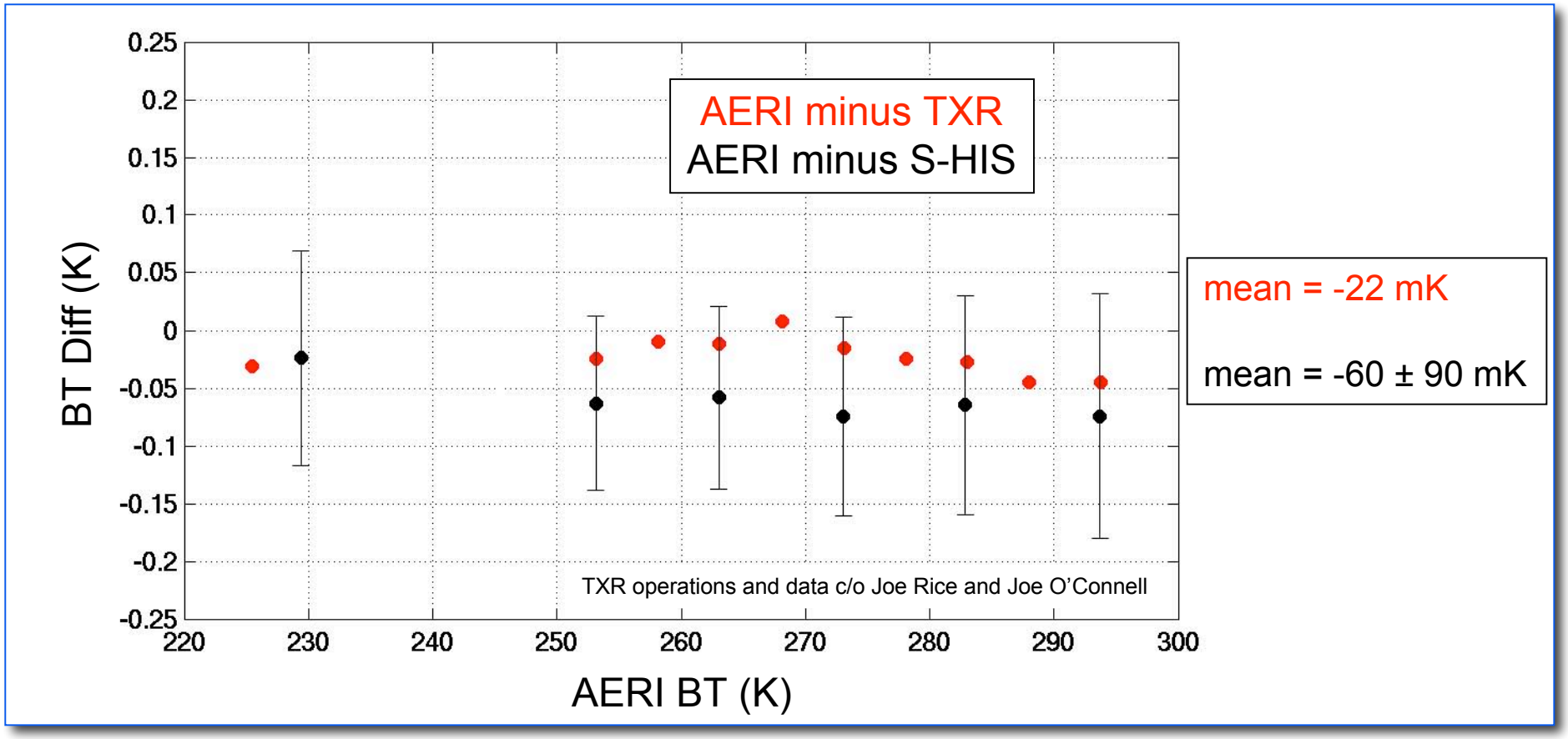
10 & 5 μm NIST TXR Channels



NIST TXR Validation of S-HIS Radiances

Preliminary Results: NIST TXR Channel 2 (10μm)

Differences wrt AERI Blackbody predicted radiance:

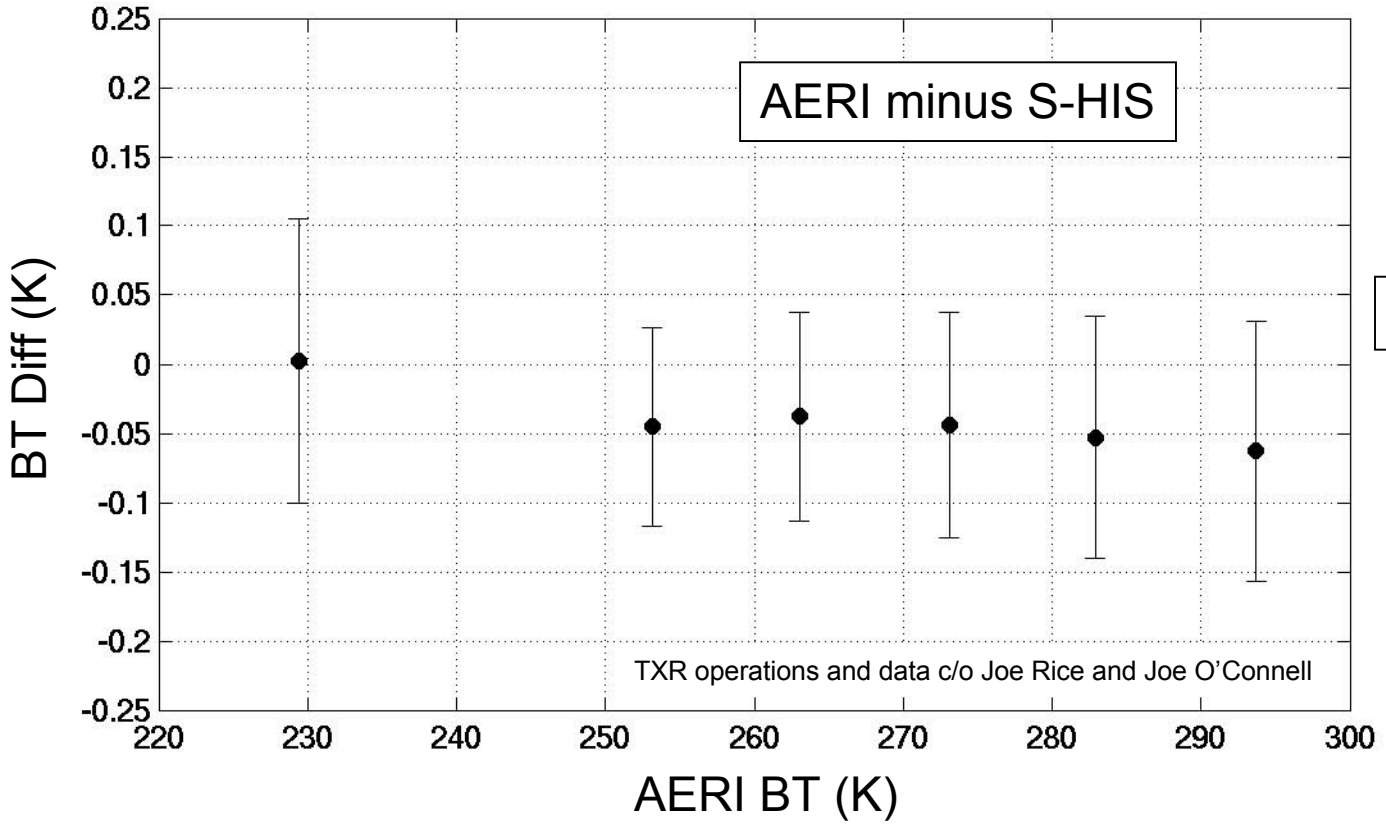


- **mean difference between TXR & S-HIS = 38 mK, well less than propagated 3-sigma uncertainties**

NIST TXR Validation of S-HIS Radiances

Preliminary Results: NIST TXR Channel 1 (5μm)

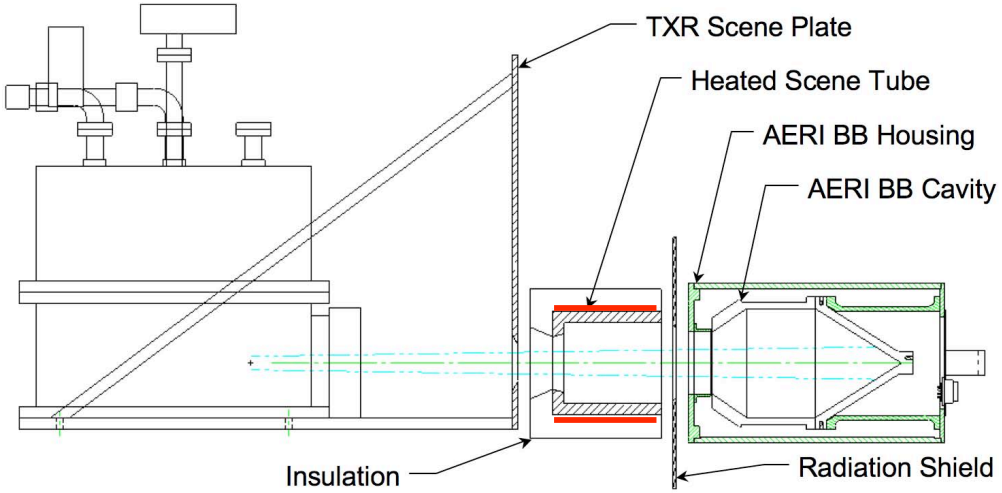
Differences wrt AERI Blackbody predicted radiance:



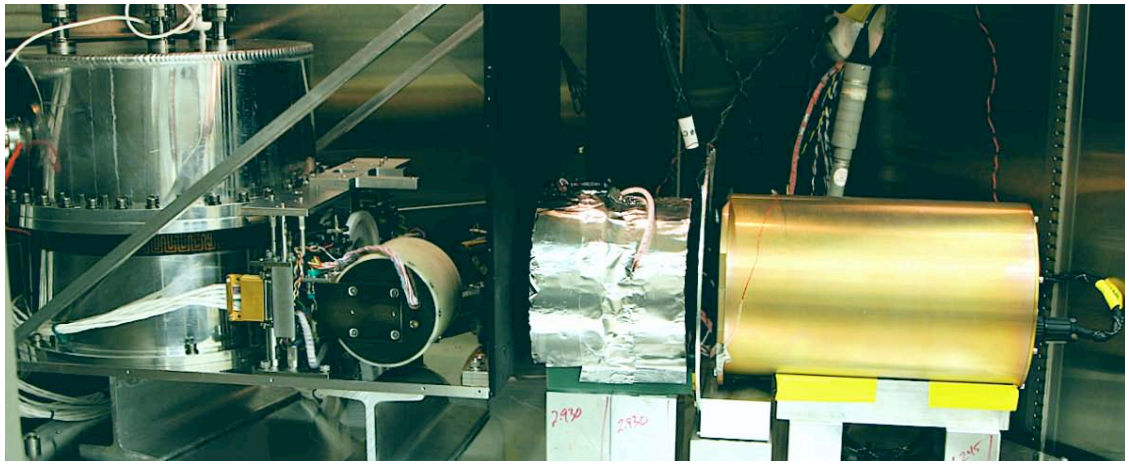
mean = -40±85 mK

- **mean difference between AERI BB & S-HIS = 40 mK**
- **TXR Ch1 analysis requires refinement at this time**

AERI Blackbody Reflectivity Test with NIST TXR Confirms Emissivity Estimates



NIST Transfer Radiometer (TXR) used to detect reflection from heated tube (up to background +100 ºC) surrounding direct FOV



January 2007

Preliminary Analysis:
5 & 10 μm emissivity
within <0.0003
of expected value
(and closer to 1)

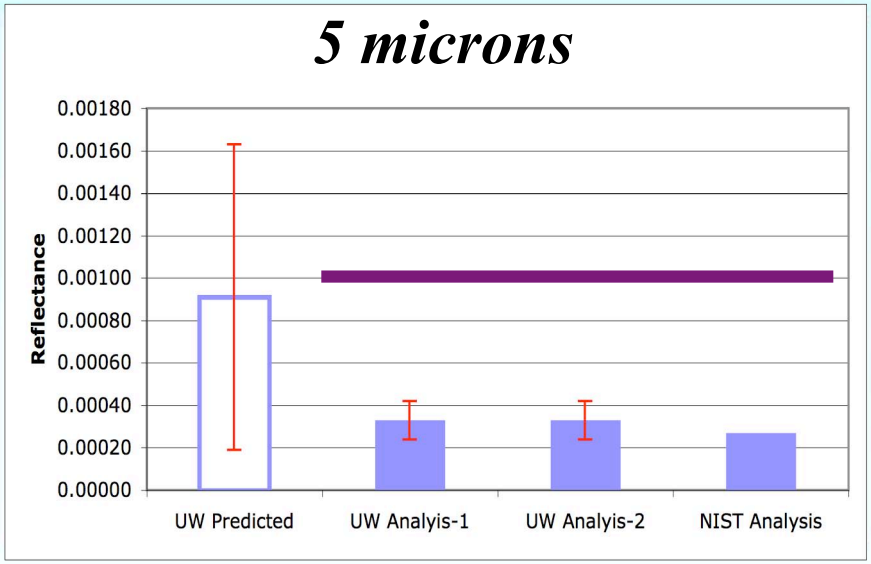
SSEC

Analysis Summary

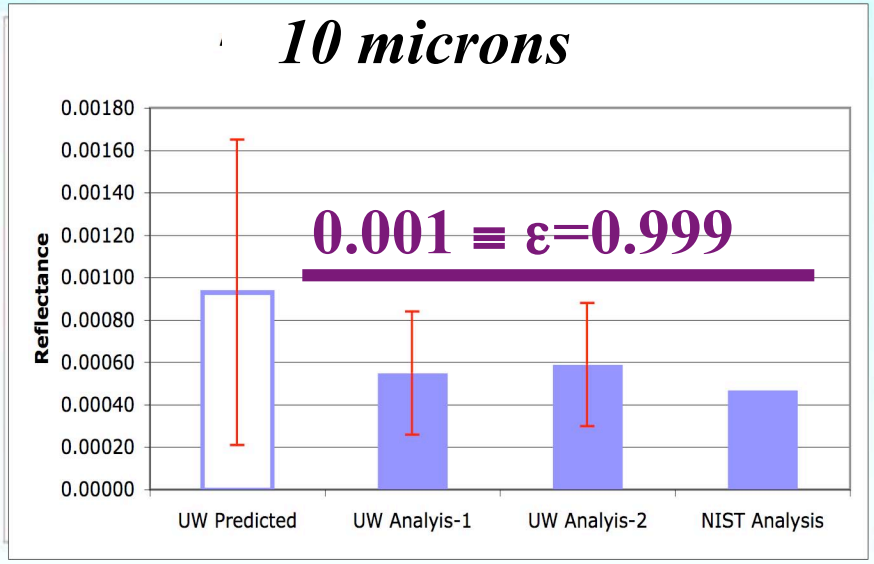
AERI Blackbody Reflectance

Updated August 07

5 microns



10 microns



Measurements confirm estimated emissivity well within uncertainty (3-sigma estimates)

*NIST analysis still being conducted

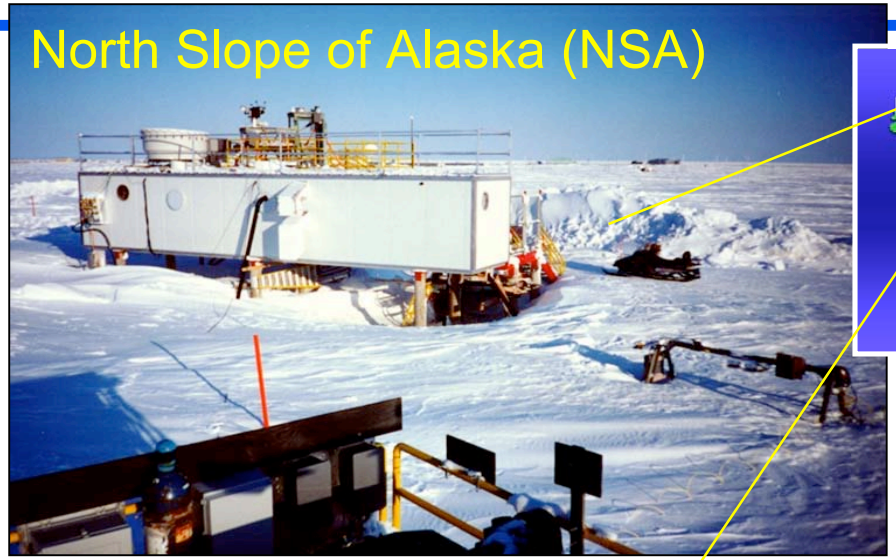
2. Retrieval Validation

- **Temperature and water vapor profiles**
- **Use three diverse ARM validation sites**
  mid-latitude/mid-continent, arctic, tropical western pacific

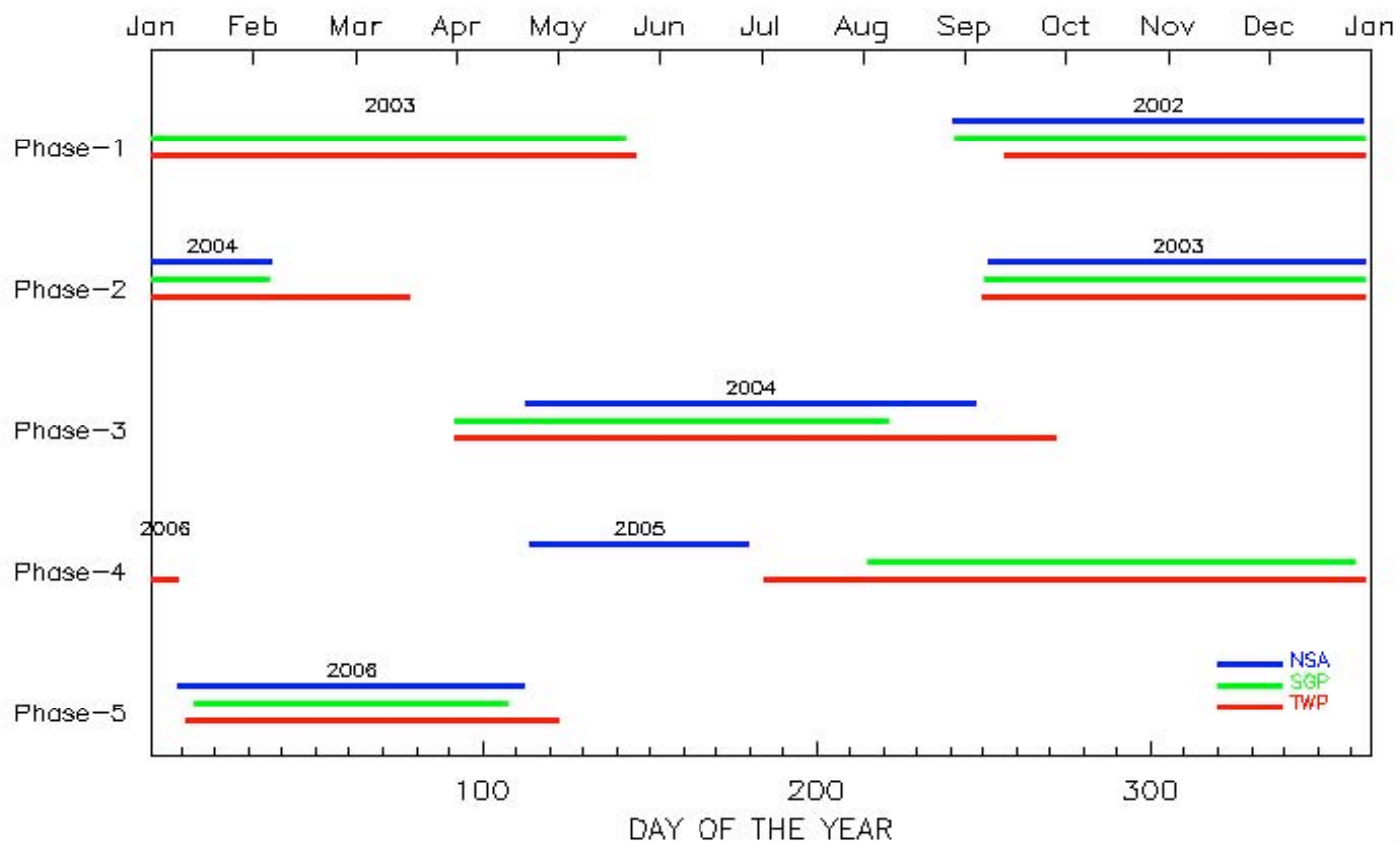
- **Approach and v4 results in Tobin et al. (2006)**

ARM represents the best available validation truth, and Dave Tobin in the best guy to interpret it

Atmospheric Radiation Measurement (ARM) Sites



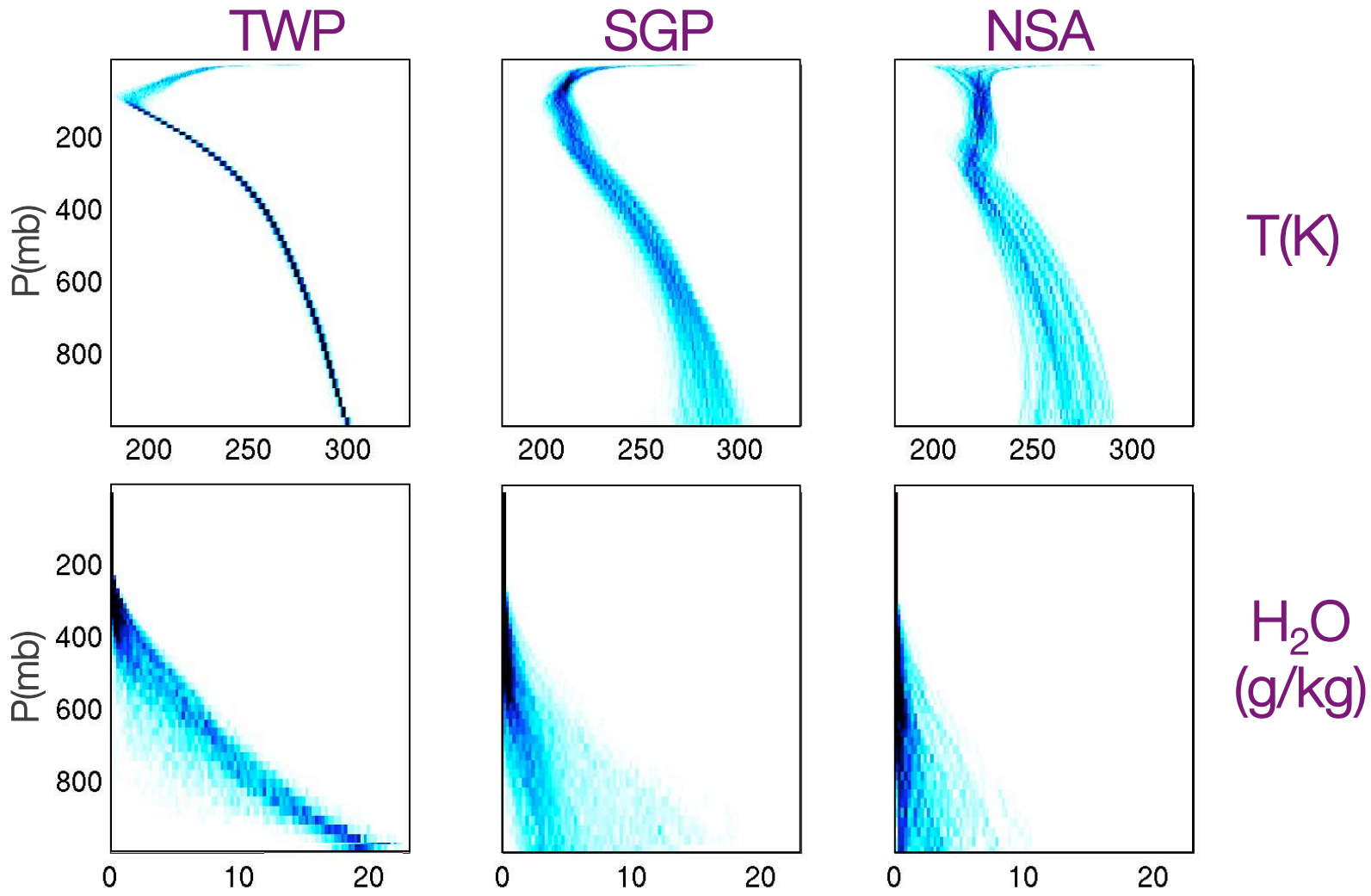
AIRS Dedicated Radiosonde Launch Phases



5 “phases” conducted to date.
90 overpasses sampled from each site for phases 1 thru 4;
60 in Phase 5.

2007 phase finishing soon, ½ AIRS and ½ IASI

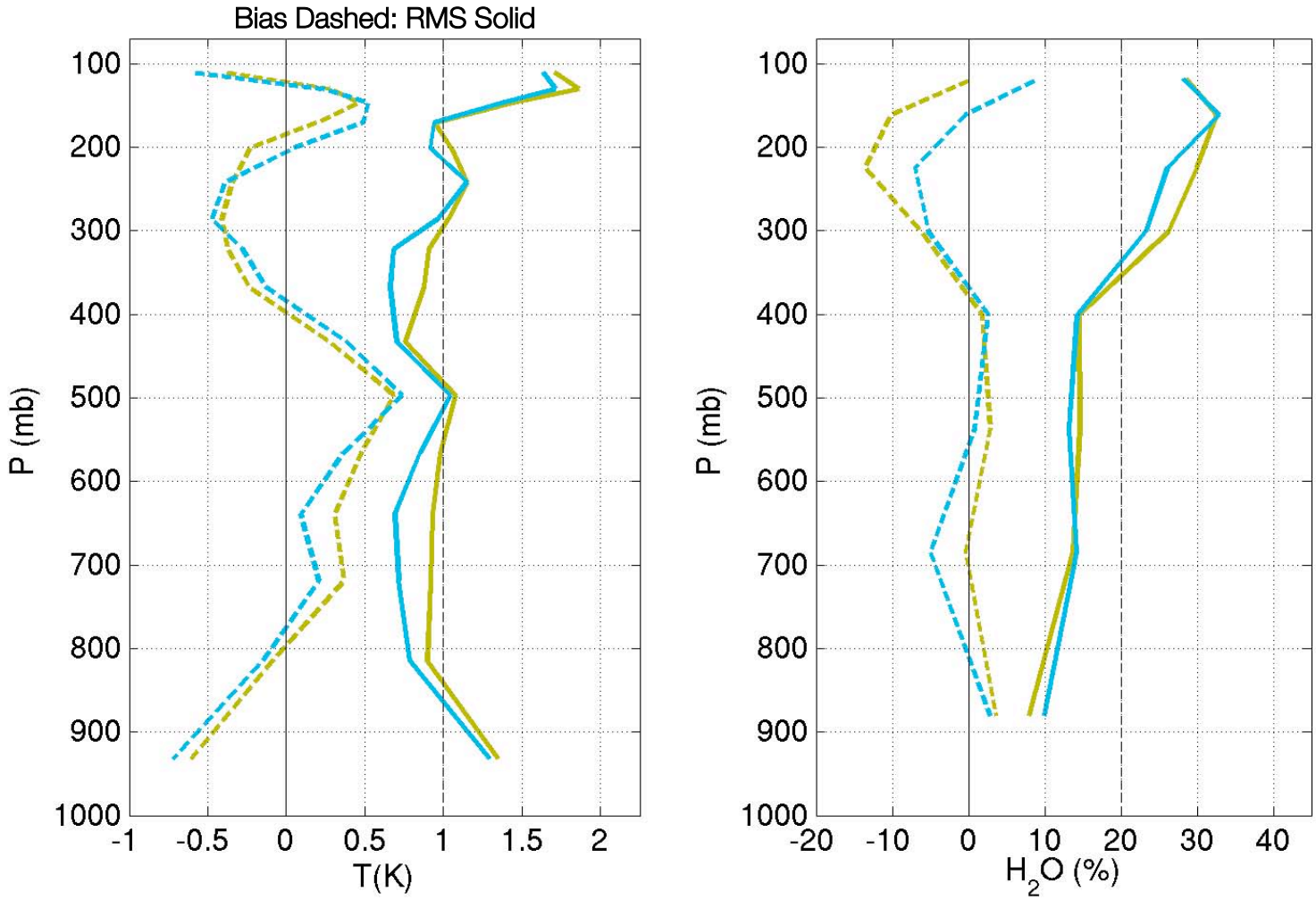
Temperature & Water Vapor Profile Distributions



Histogram of occurrence with higher being darker blue

TWP, v5-ARM and v4-ARM using v5 QC

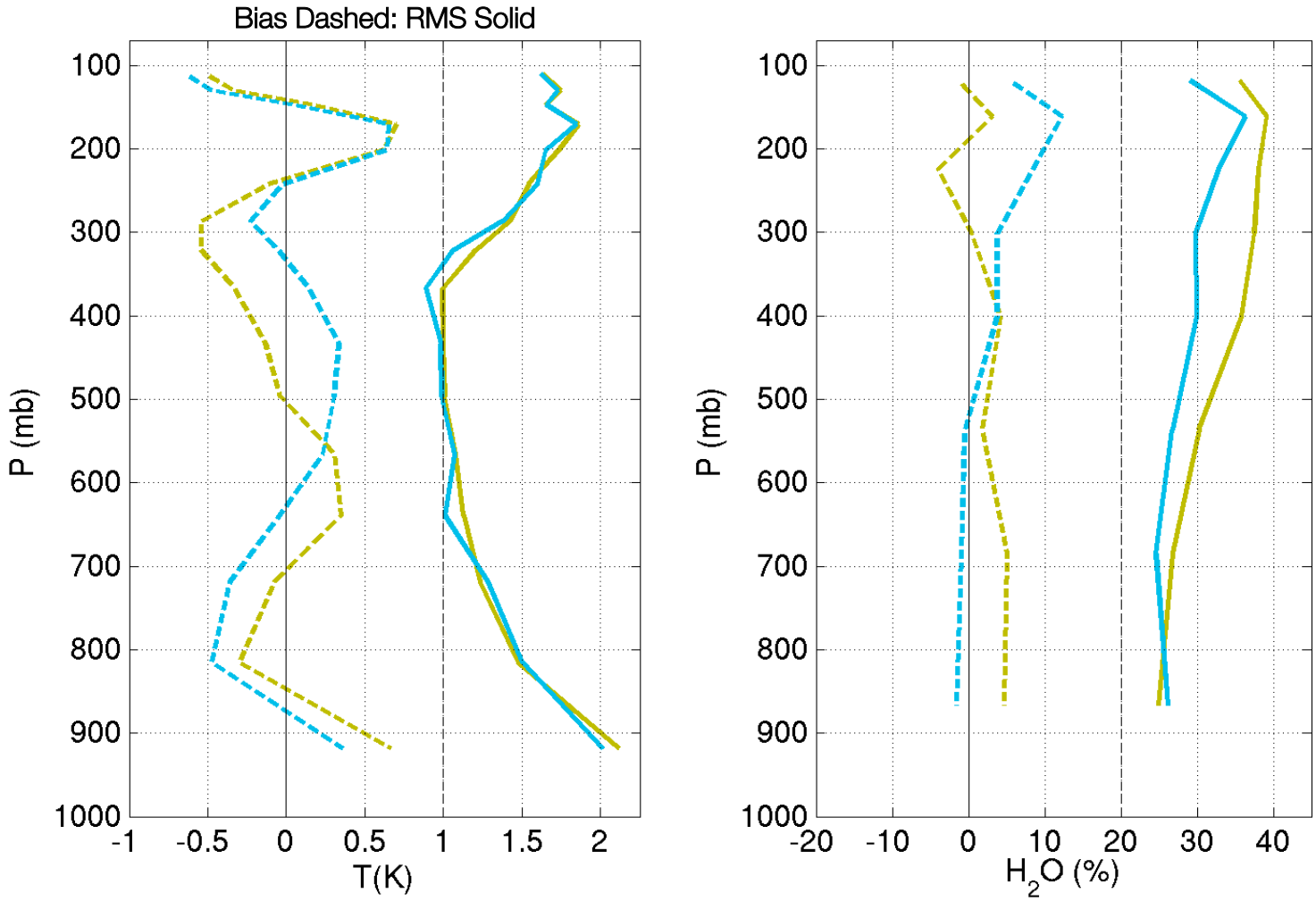
(v5 Pgood @surface)



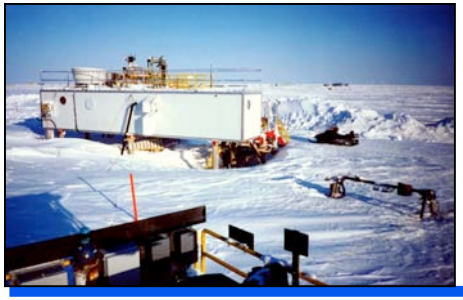
Performance generally good, slight improvement in V5

SGP, v5-ARM and v4-ARM using v5 QC

(v5 Pgood @surface)

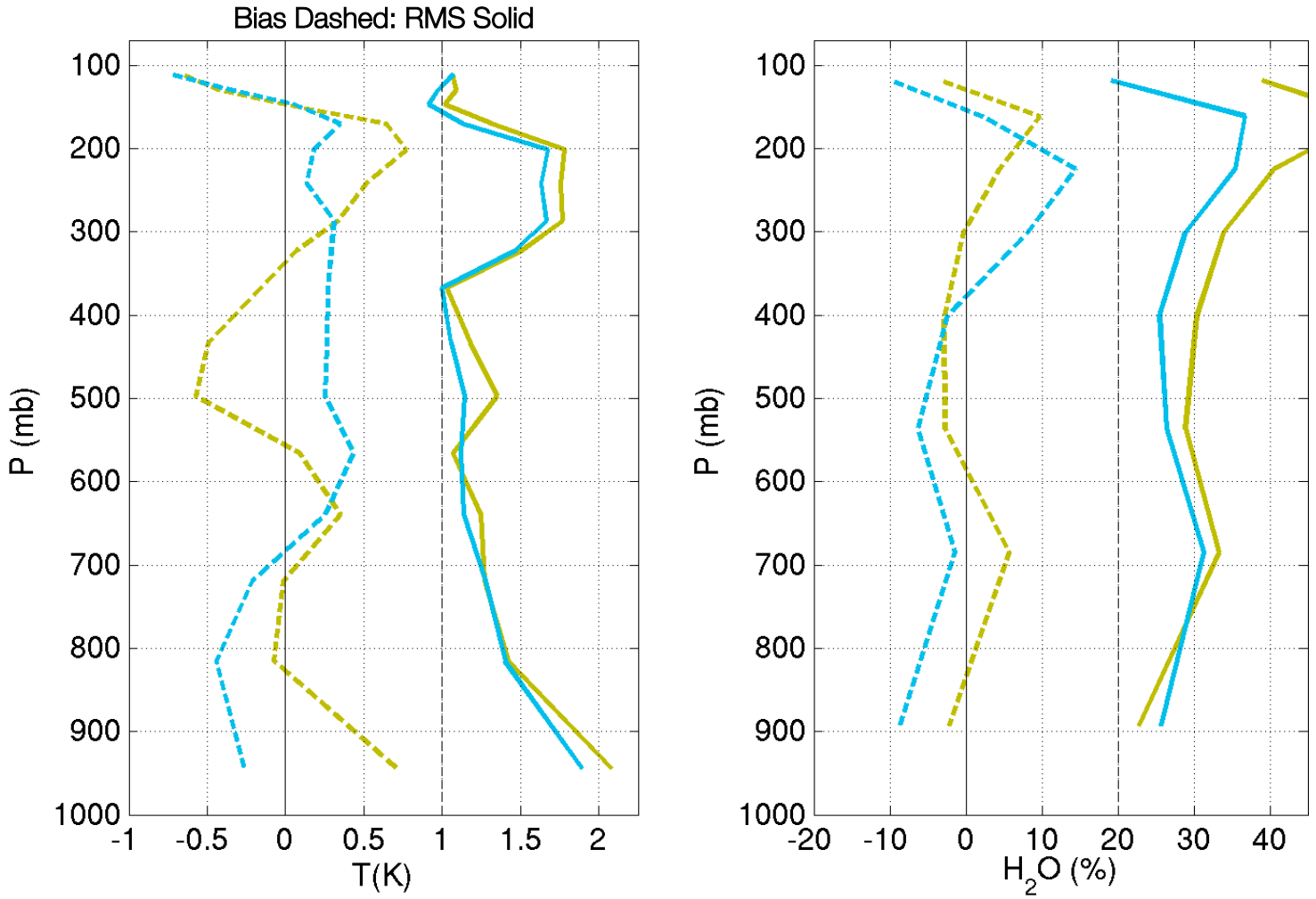


Still not good P >750 mb, but Water Vapor significantly improved



NSA, v5-ARM and v4-ARM using v5 QC

(v5 Pgood @surface)

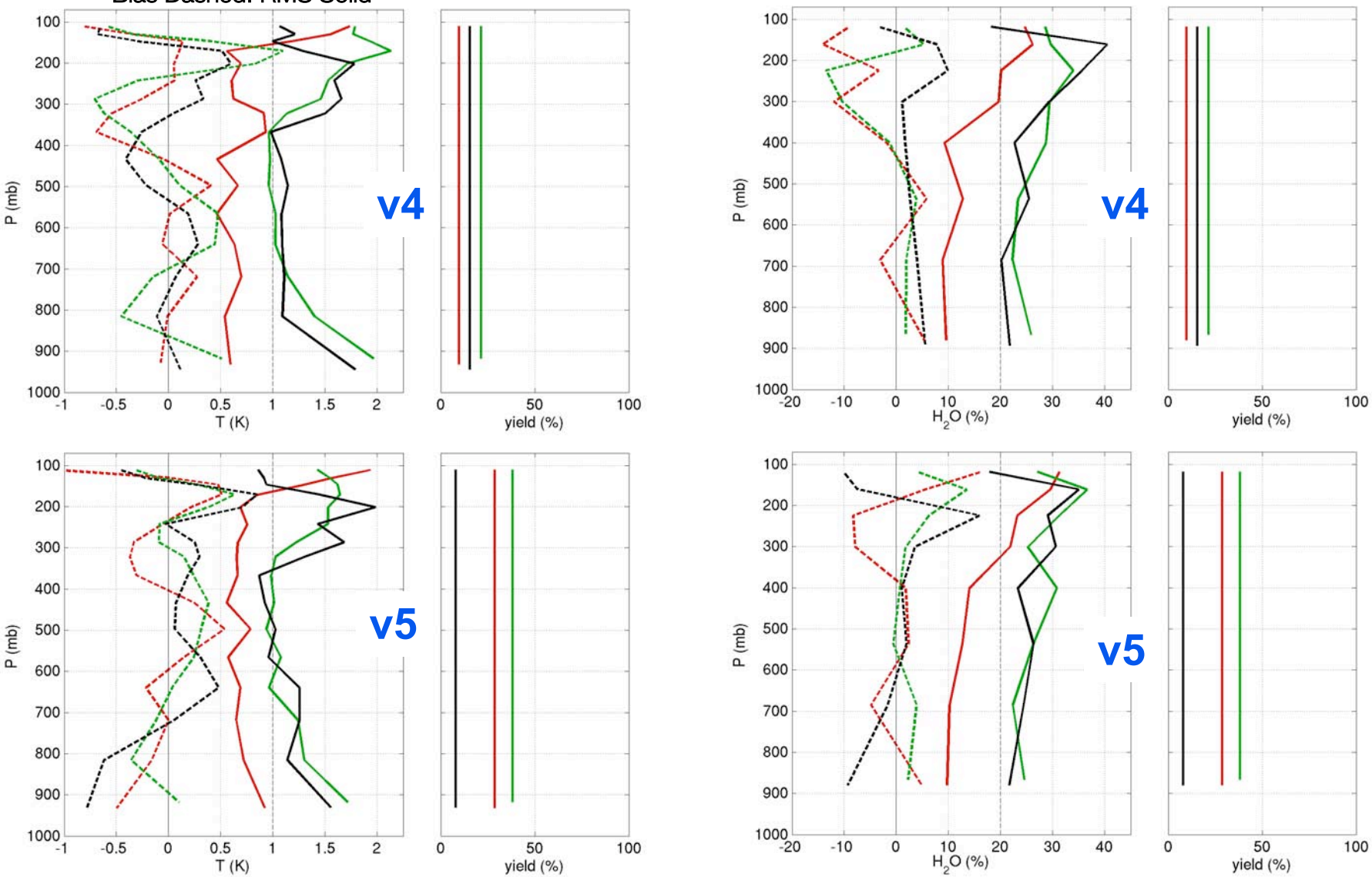


Surprisingly similar to SGP

Best Quality Retrievals: TWP, SGP, NSA

(Temperature at all levels, H_2O, and Surface* best quality)

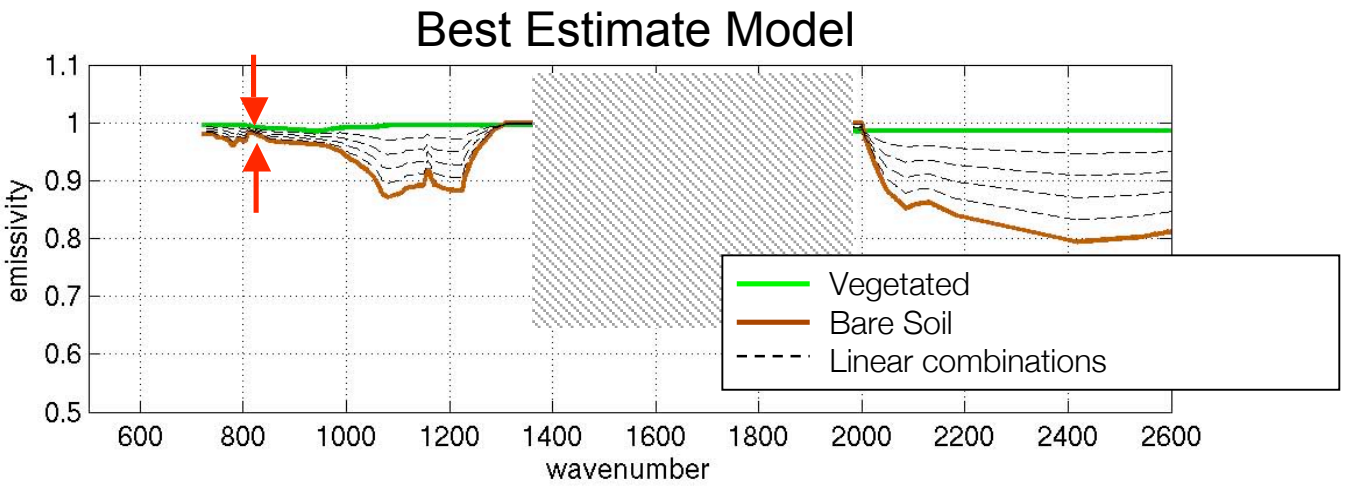
Bias Dashed: RMS Solid



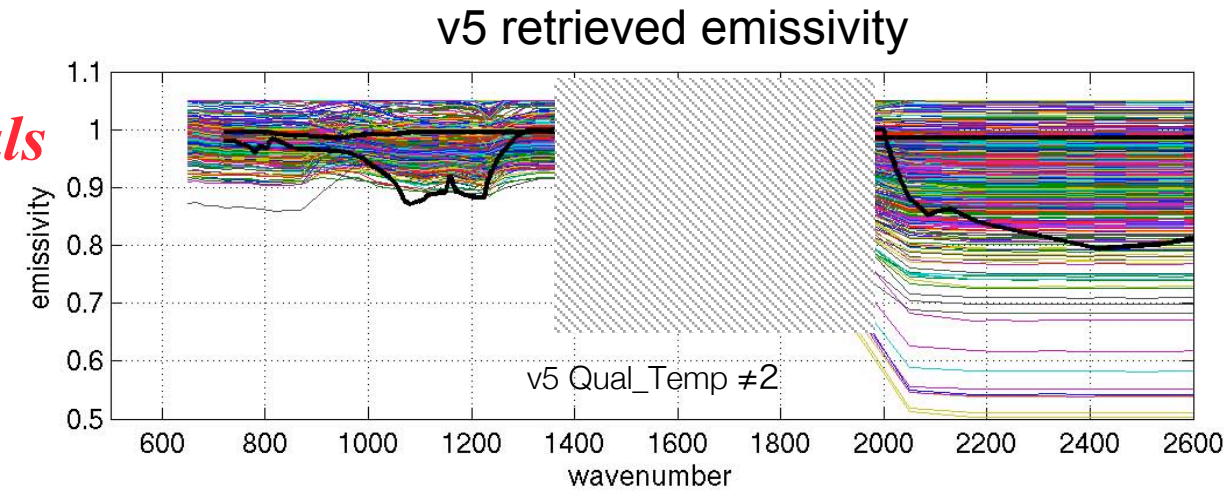
Note similarity of SGP & NSA

SGP: Land Surface Emissivity Problem

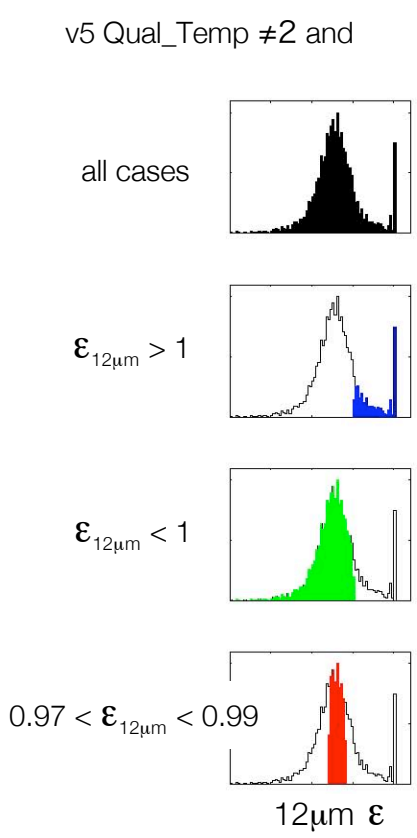
Based on UW AERI

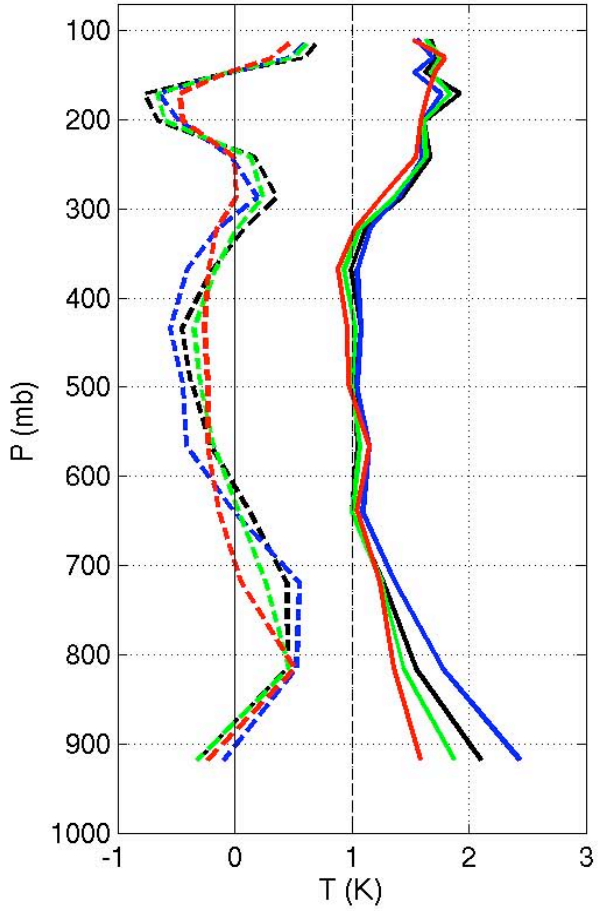


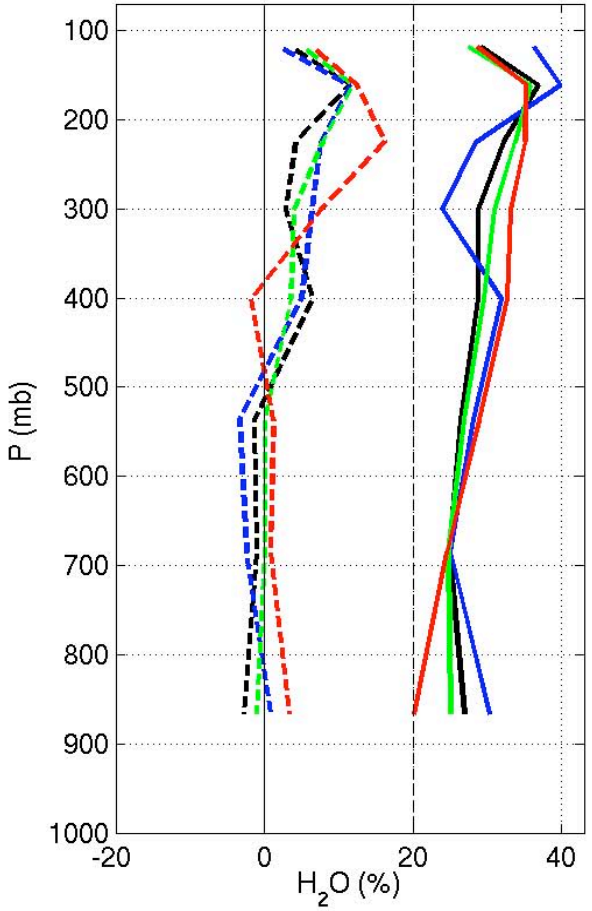
AIRS retrievals not a very good match



SGP: Dependence of Retrieval Performance on Emissivity







The Good News: Significant improvement in lower trop RMS for both T and q when the retrieved $\varepsilon_{12\mu m}$ is within range of SGP best estimates

3. AIRS OLR Product (Outgoing Longwave Radiation): Validation for Clear Skies

- **Alternative Radiative Transfer Model: RRTM applied to 16 Nov. 2002 AIRS retrievals for comparison to the TOVS model used for AIRS v5 L2 OLR**

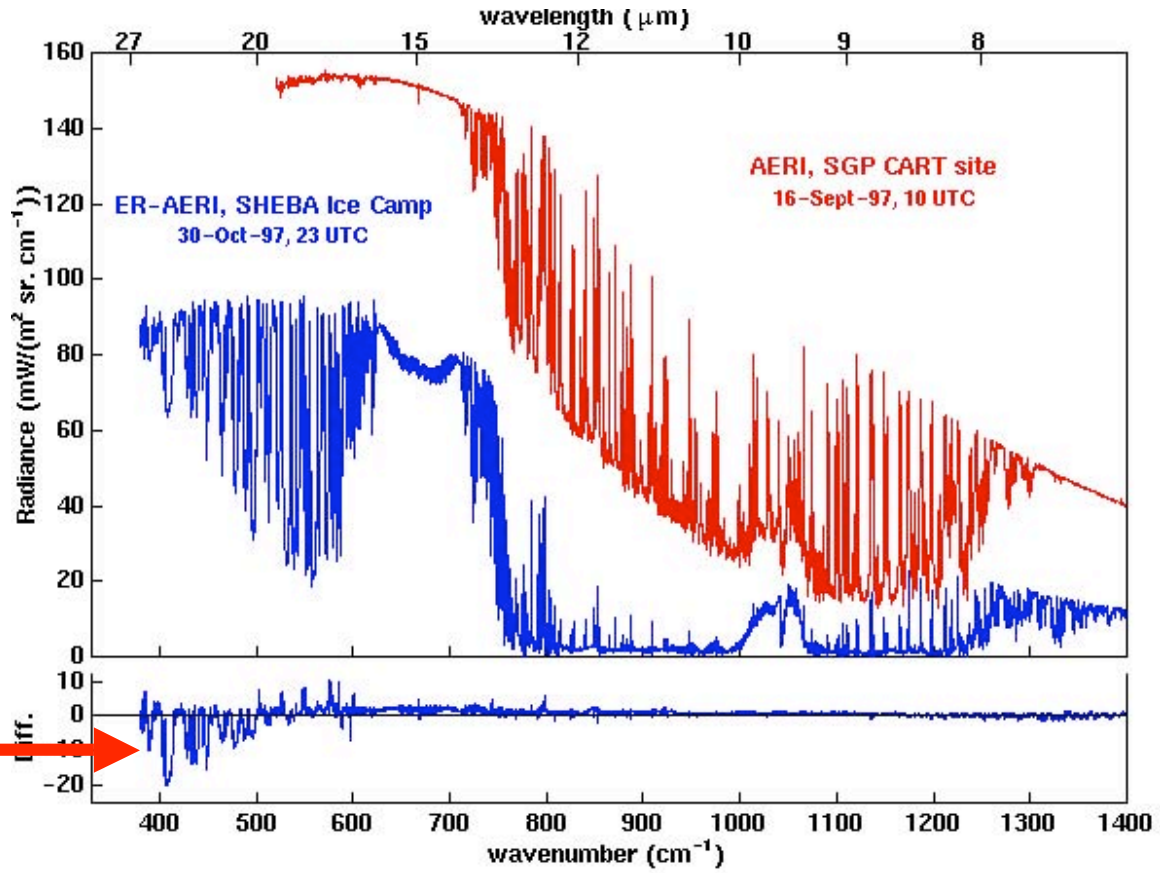
- **CERES SSF OLR comparisons performed**
  (AIRS FOV defined as clear if all averaged CERES pixels had clear fractions greater than 99%)

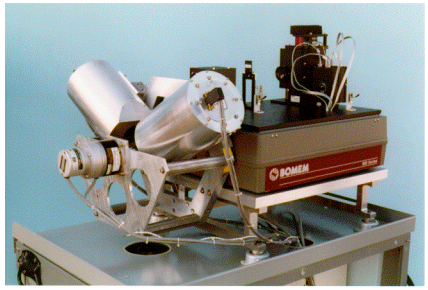
We are working with Joel Susskind on this one

RRTM v3.01 from AER
(Tony Clough, et al.)

- Correlated k-distribution model
- Based on LBLRTM, line-by-line model developed under the ARM Program using AERI, microwave, & and a wide range of other data
- Computes LW and SW atmospheric flux and cooling rate profiles, clear and cloudy
- GCM version used in ECMWF and other Global Models
- Code and more information online at http://www.rtweb.aer.com

AERI Observations During SHEBA Improve Far-Infrared Radiative Transfer Models





Tobin et al., JGR, 1999

Obs-Calc using CKDv0 continuum model (Clough 1989)

300% error in water vapor continuum absorption model in far infrared (18-25 μm)

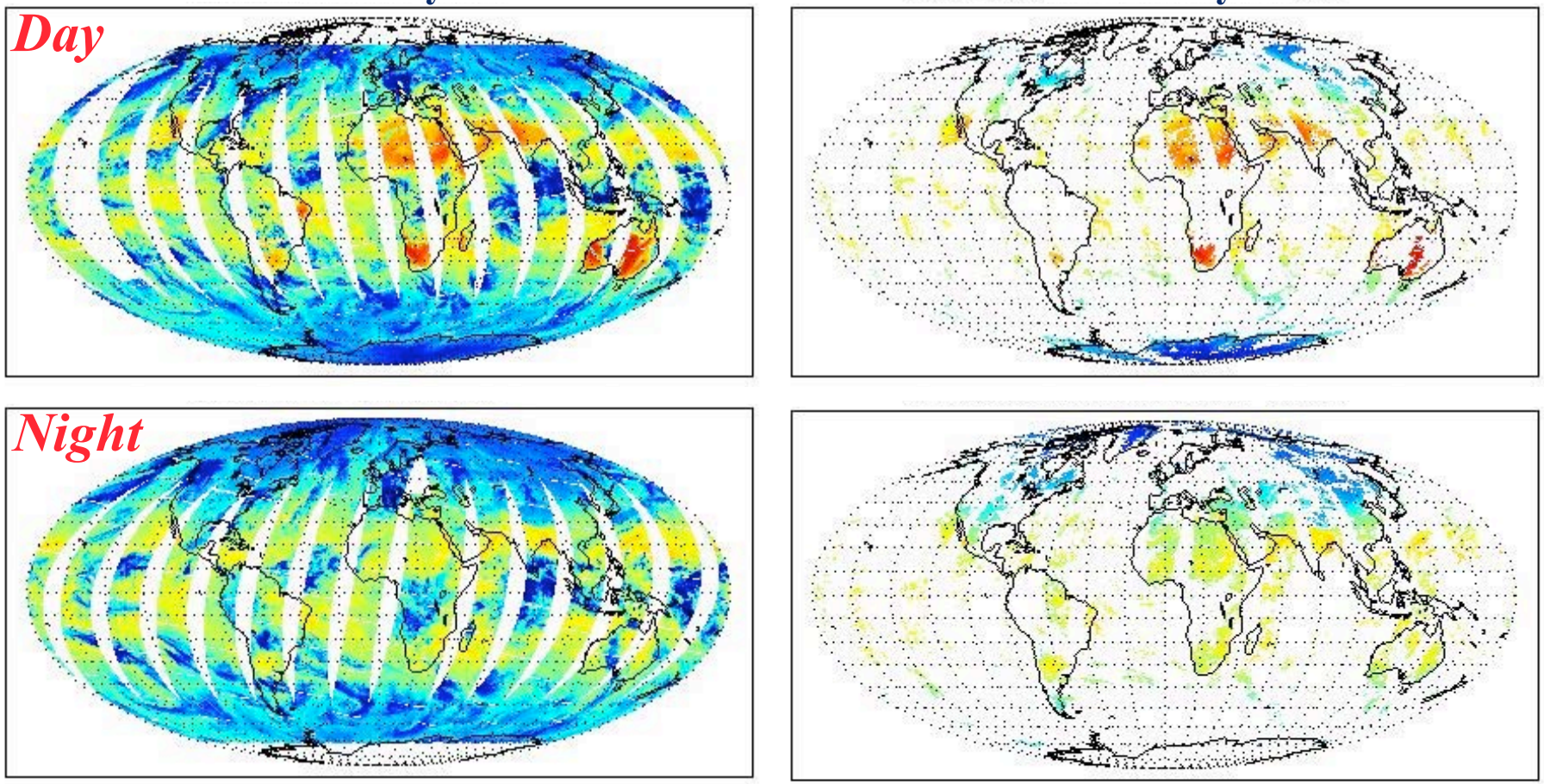
Led to improved representation of far-IR H_2O continuum absorption in the MT_CKD continuum model, included in LBLRTM and RRTM.

CERES OLR Maps

(16 Nov 2002)

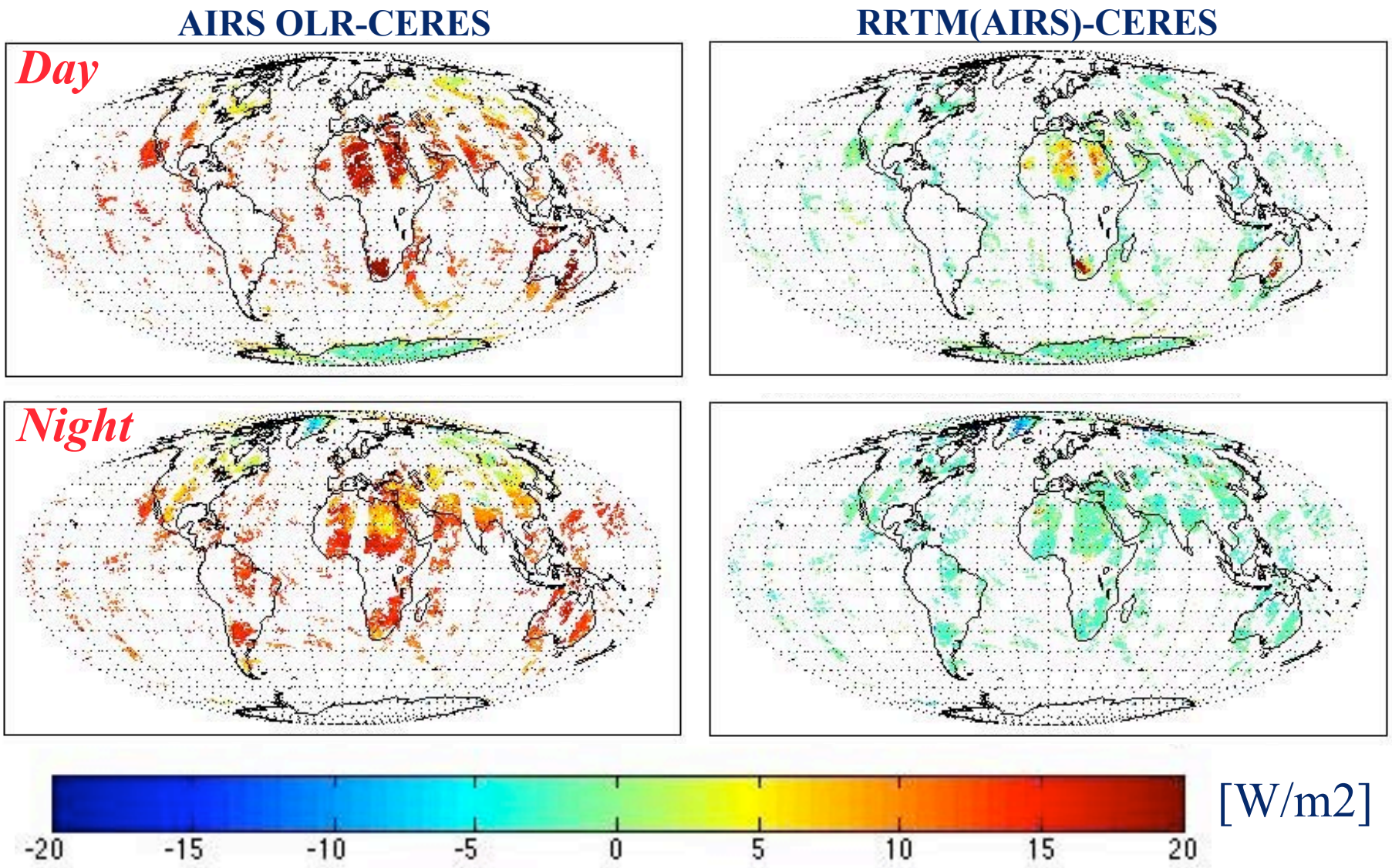
All Sky

Clear Sky



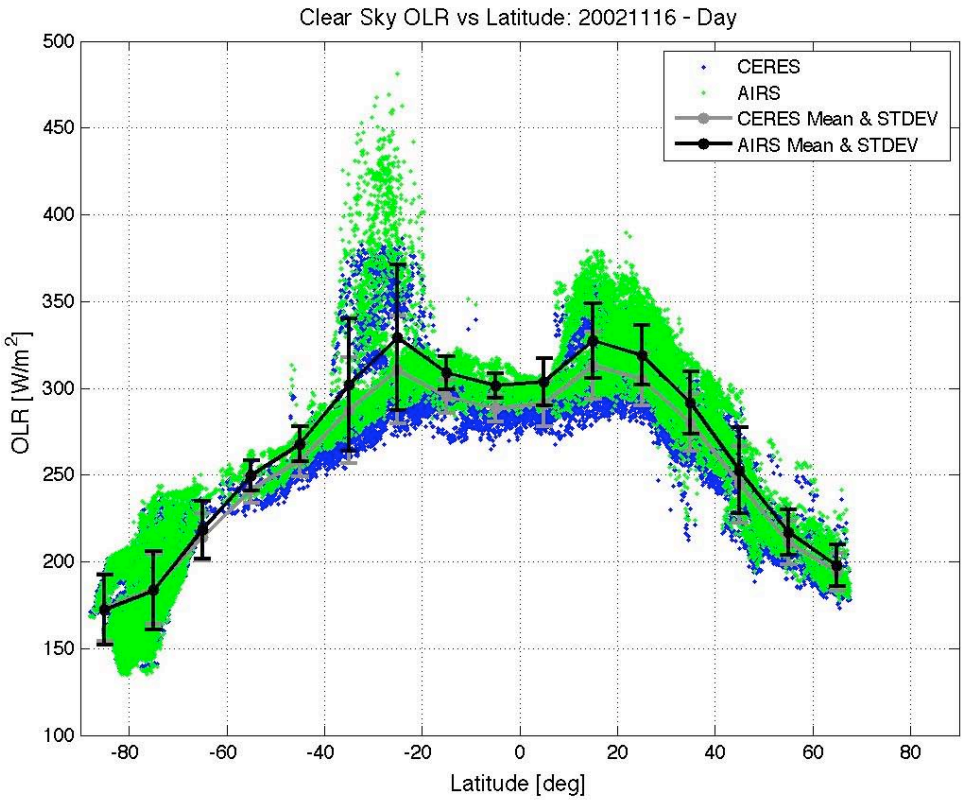
AIRS-CERES Clear OLR Maps

(16 Nov 2002)

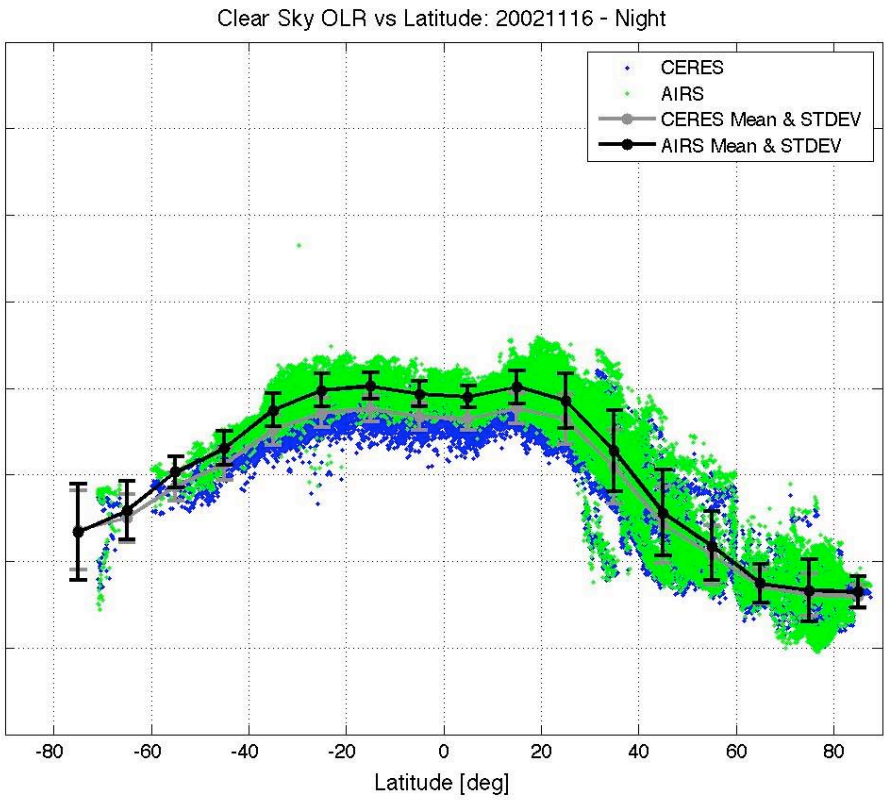


Latitude Dependence of Clear Sky
AIRS OLR and CERES OLR

Day



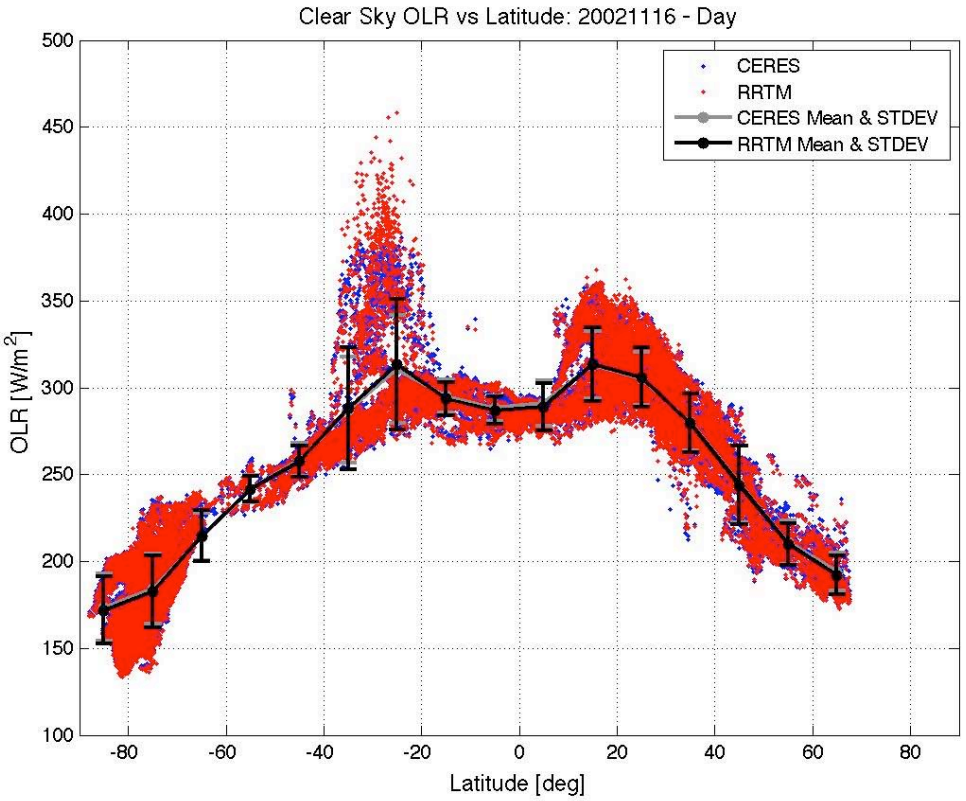
Night



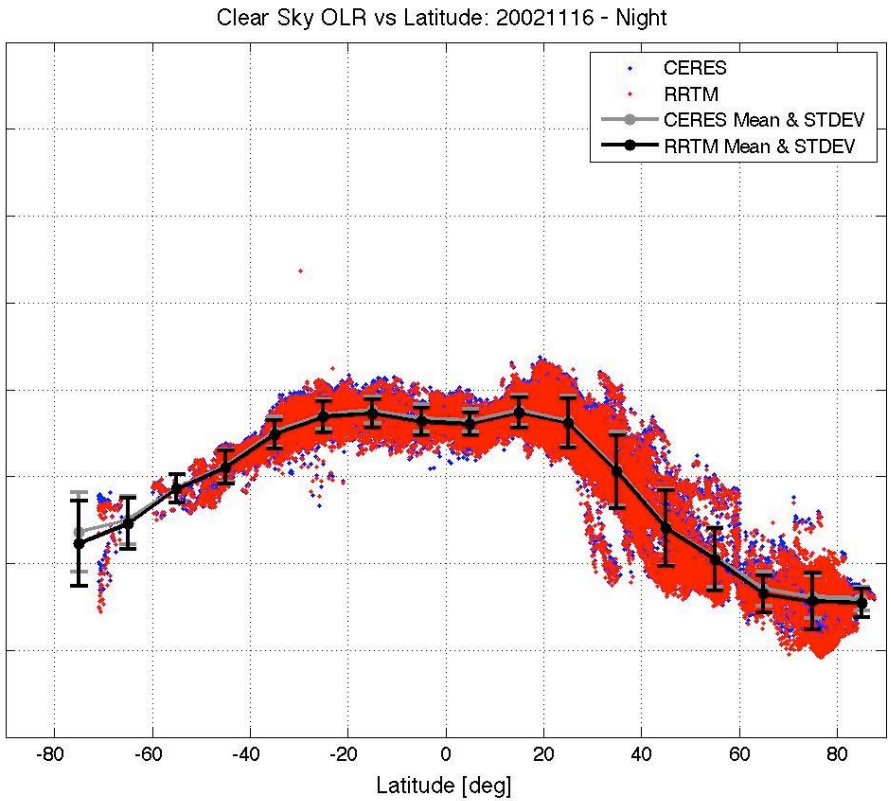
AIRS OLR consistently larger than CERES (order 4%)

Latitude Dependence of Clear Sky
RRTM(AIRS) and CERES OLR

Day



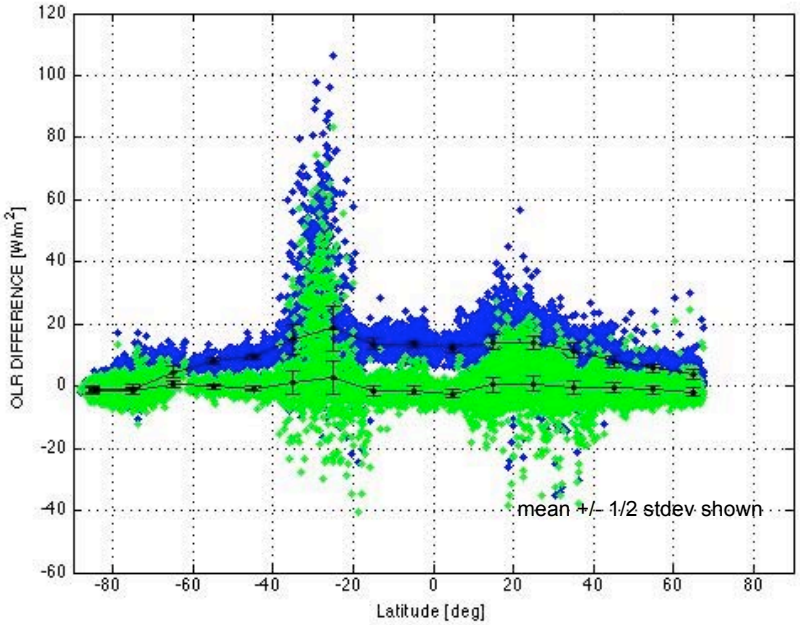
Night



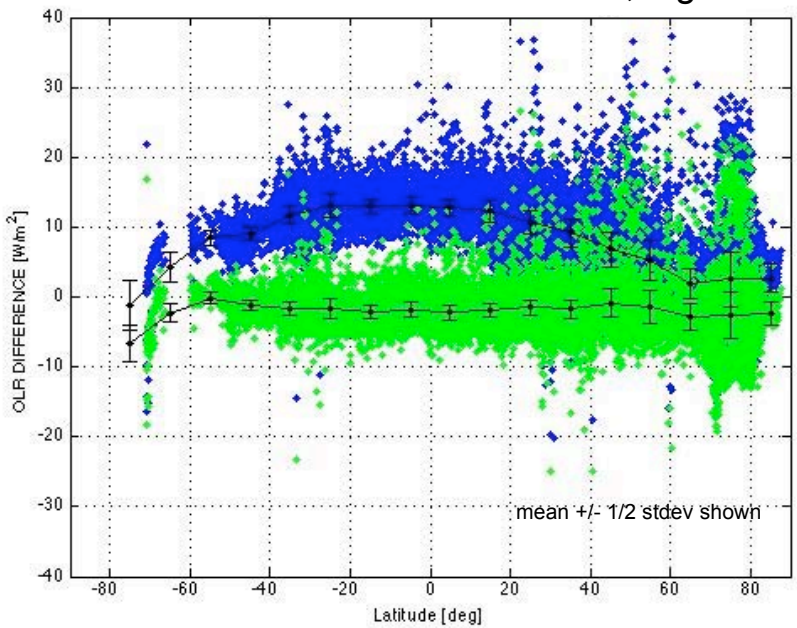
Good agreement--hard to tell them apart here

Latitude Dependence of AIRS OLR – CERES and RRTM(AIRS) - CERES

AIRS-CERES & RRTM-CERES, daytime



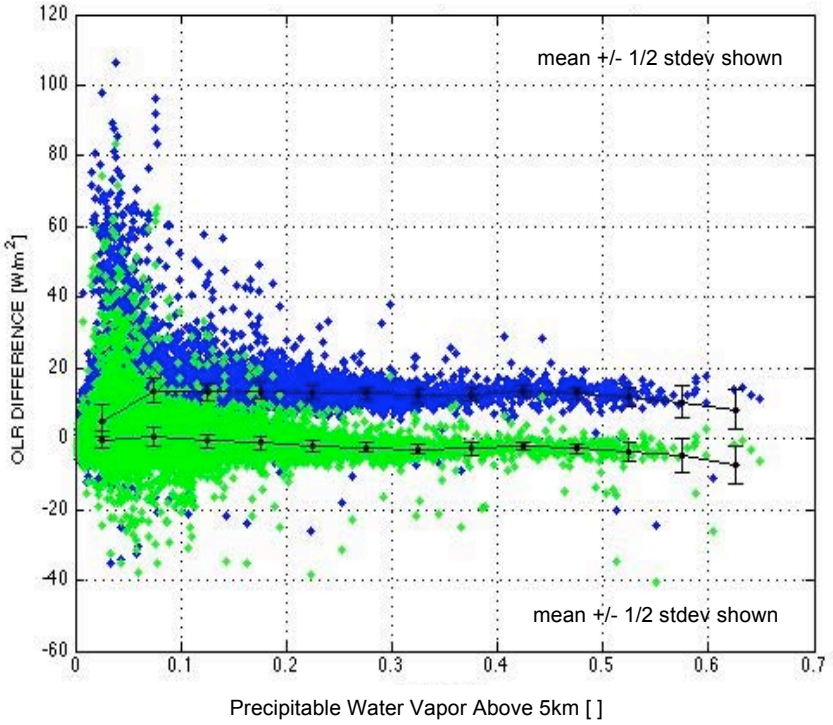
AIRS-CERES & RRTM-CERES, night



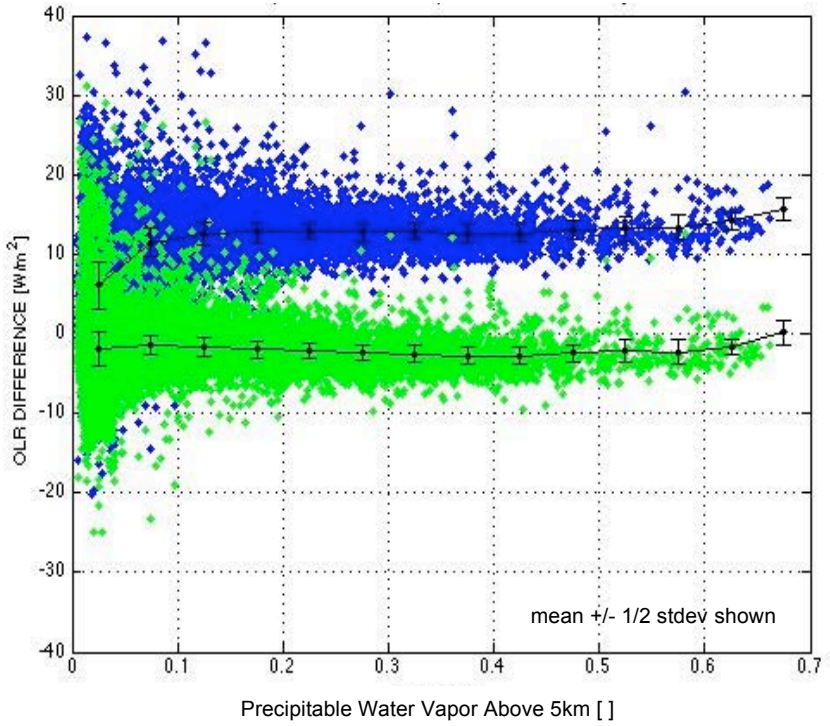
	Day (npts = 24,365)		**Night** (npts = 23,286)	
	Mean	Stdev	Mean	Stdev
AIRS-CERES	9.4	5.5	8.7	8.8
RRTM-CERES	-1.8	3.3	-0.39	4.8

Upper Level Water Vapor Dependence of AIRS OLR – CERES and RRTM(AIRS) - CERES

AIRS-CERES & RRTM-CERES, daytime

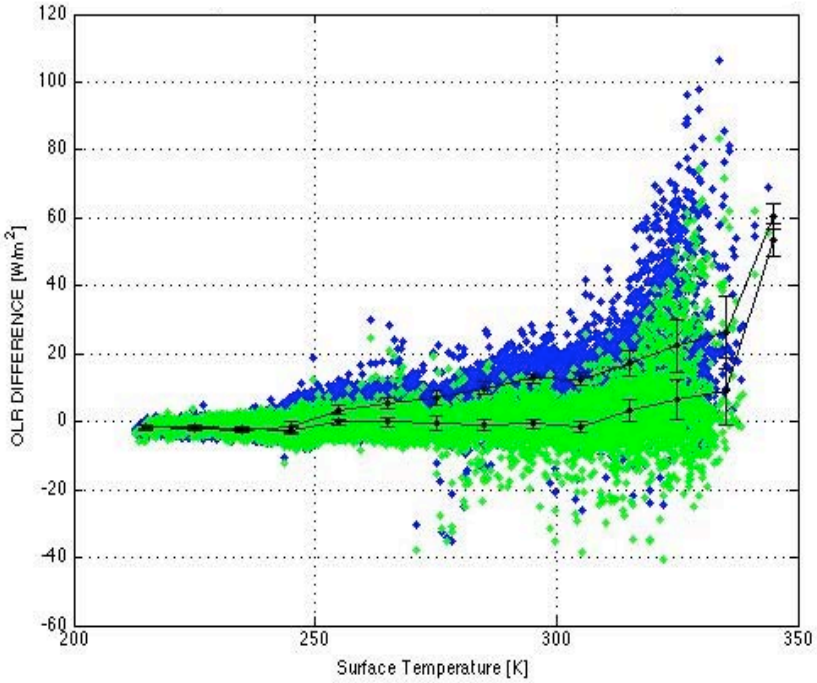


AIRS-CERES & RRTM-CERES, night

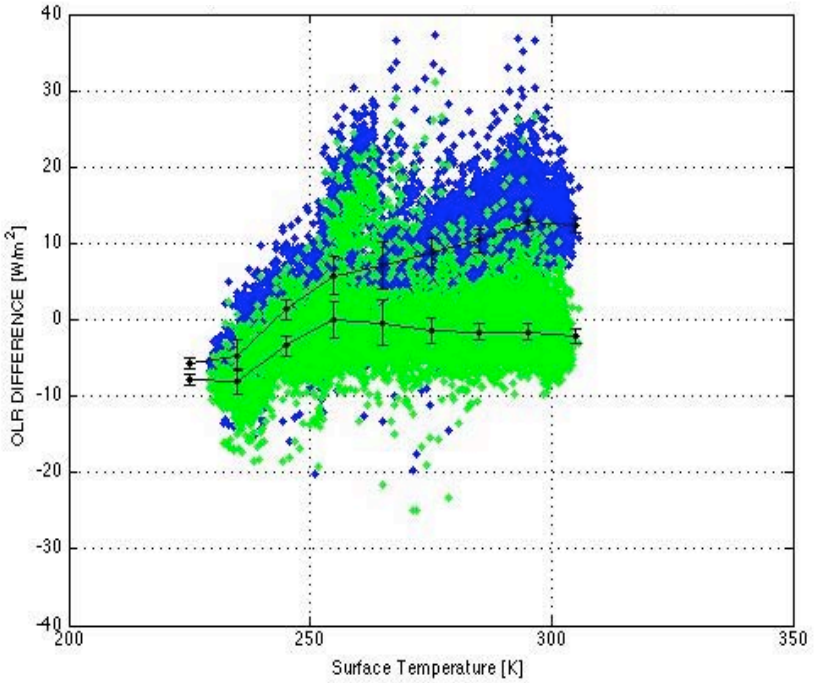


Surface Temperature Dependence of AIRS OLR – CERES and RRTM(AIRS) - CERES

AIRS-CERES & RRTM-CERES, daytime



AIRS-CERES & RRTM-CERES, night



Conclusions

- Radiance Validation from aircraft platforms is excellent—needs to be continued until there is a well established alternative—e.g.CLARREO!!
- ARM site crucial as the most accurate atmospheric characterization for T/Q Retrieval Validation—future needs to be planned collaboratively with IPO
- AER's RRTM compares substantially better to CERES SSF than the current AIRS OLR*. The clear sky RRTM-CERES bias is about -1 W/m^2 (versus +9 W/m^2), and has no latitudinal dependence. **In fact, it is possible that the RRTM(AIRS) is more accurate than CERES itself.**

*Note the NASA AIRS L2 OLR model (Susskind) was developed ~1975 when there were still many outstanding spectroscopy issues

Backup Slides: Scanning HIS

UW Scanning HIS: 1998-Present

(HIS: High-resolution Interferometer Sounder, 1985-1998)

Characteristics

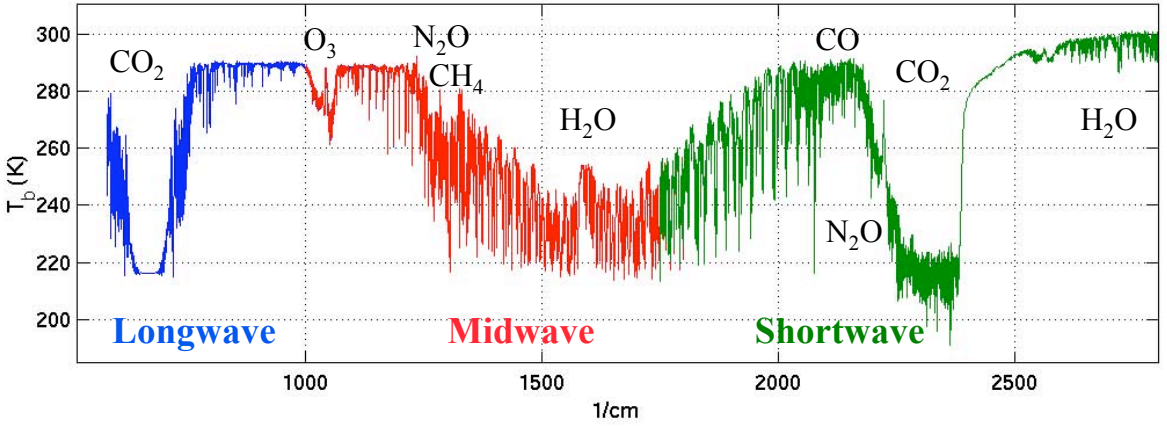
Spectral Coverage: 3-17 microns

Spectral Resolution: 0.5 cm^{-1}

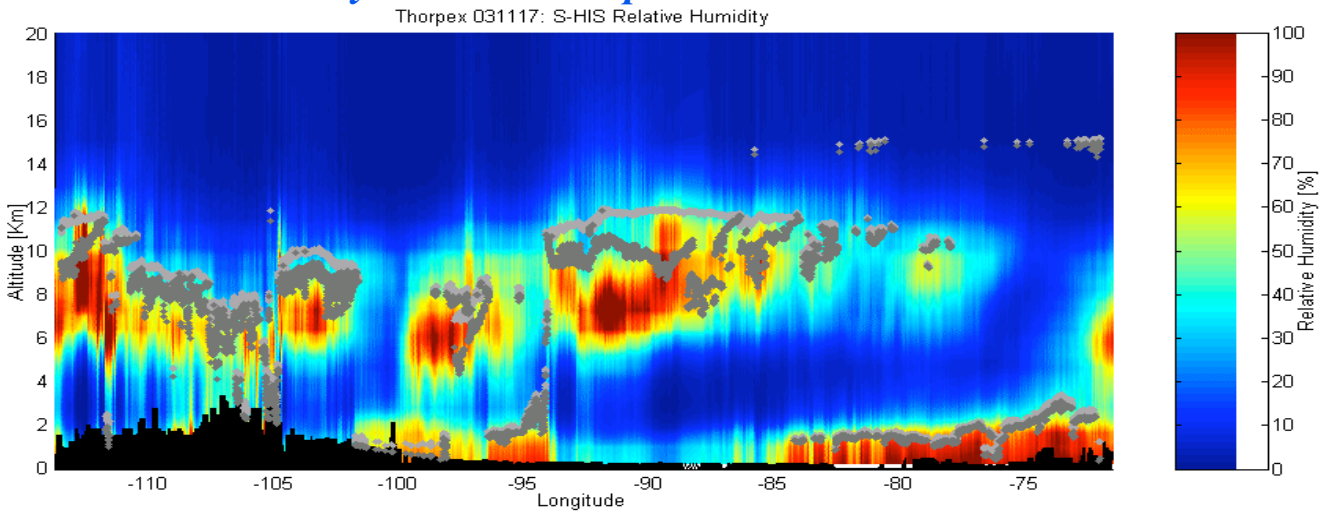
Resolving power: 1000-6000

Footprint Diam: 2 km @ 20 km

Cross-Track Scan: Programmable including uplooking zenith view



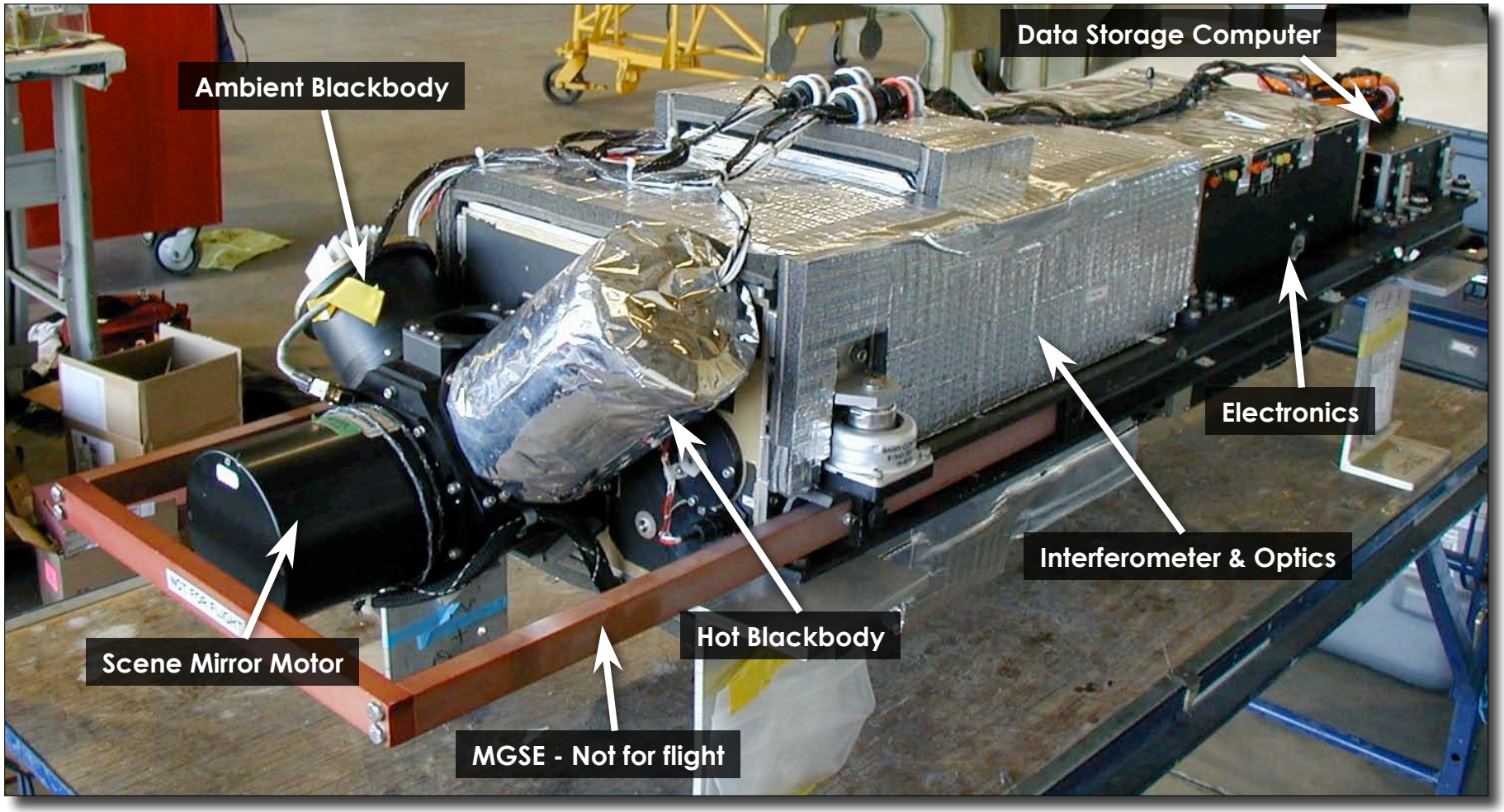
Relative Humidity Retrieval compared to lidar cloud boundaries



Applications:

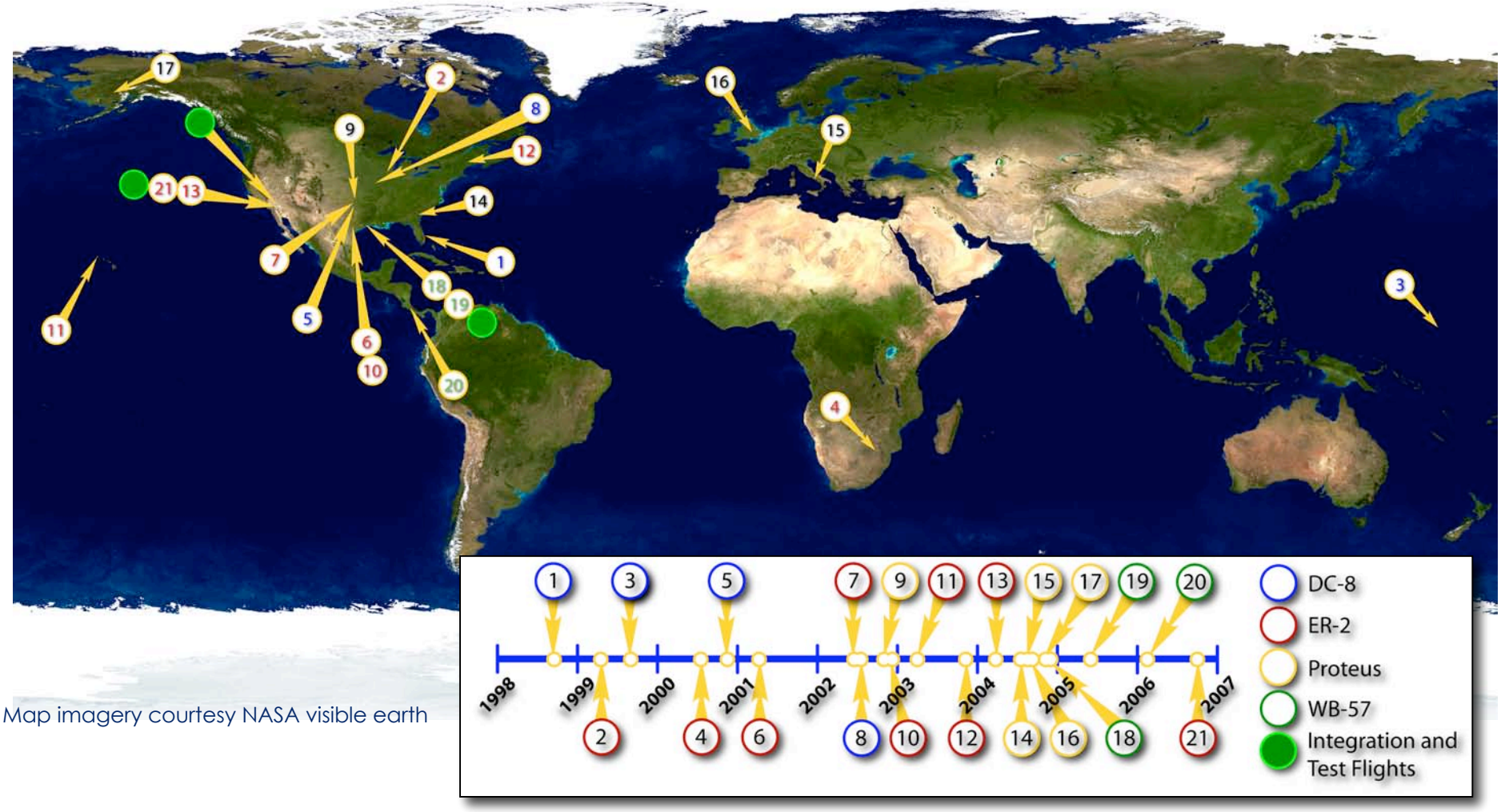
- Radiances for Validation & Radiative Transfer
- Temp & Water Vapor Retrievals
- Cloud Radiative Prop.
- Surface Emissivity & T
- Trace Gas Retrievals

UW Scanning HIS



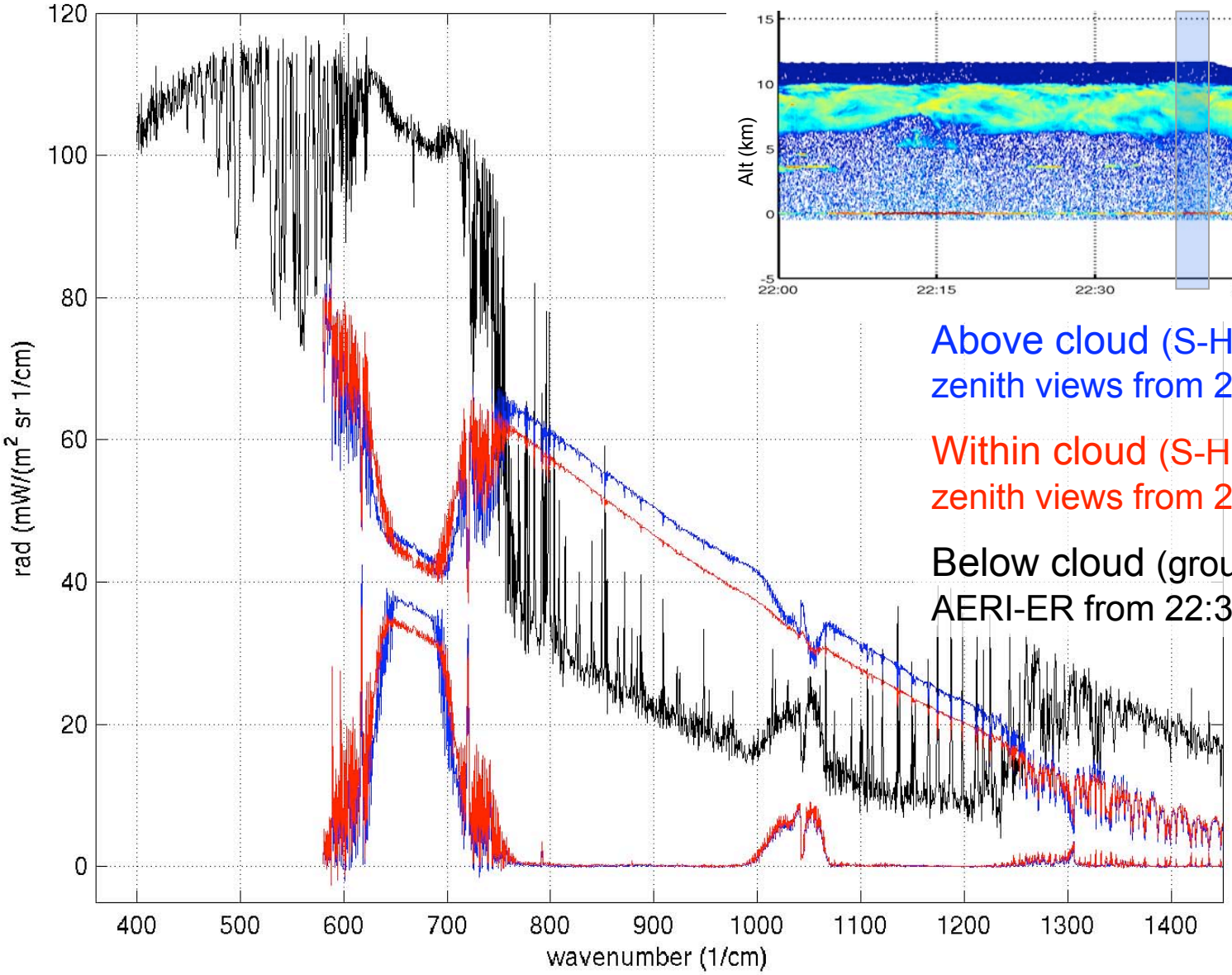
S-HIS Aircraft Platforms

S-HIS Flight Experience



Map imagery courtesy NASA visible earth

Sample Scanning HIS up and down views (from arctic MPACE, 10/17/04)

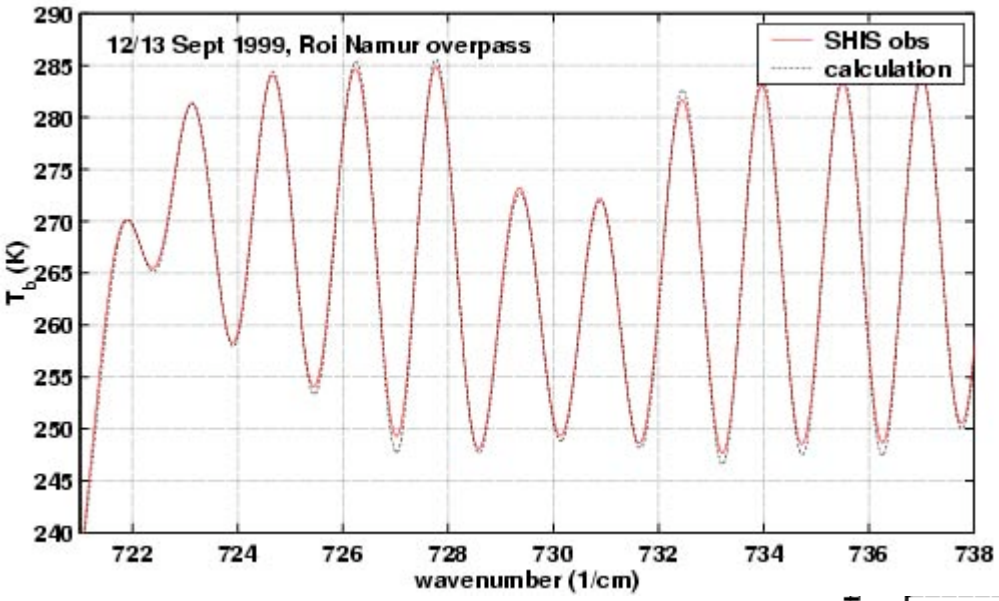


Above cloud (S-HIS nadir and zenith views from 22:35 to 22:40)

Within cloud (S-HIS nadir and zenith views from 22:55 to 23:00)

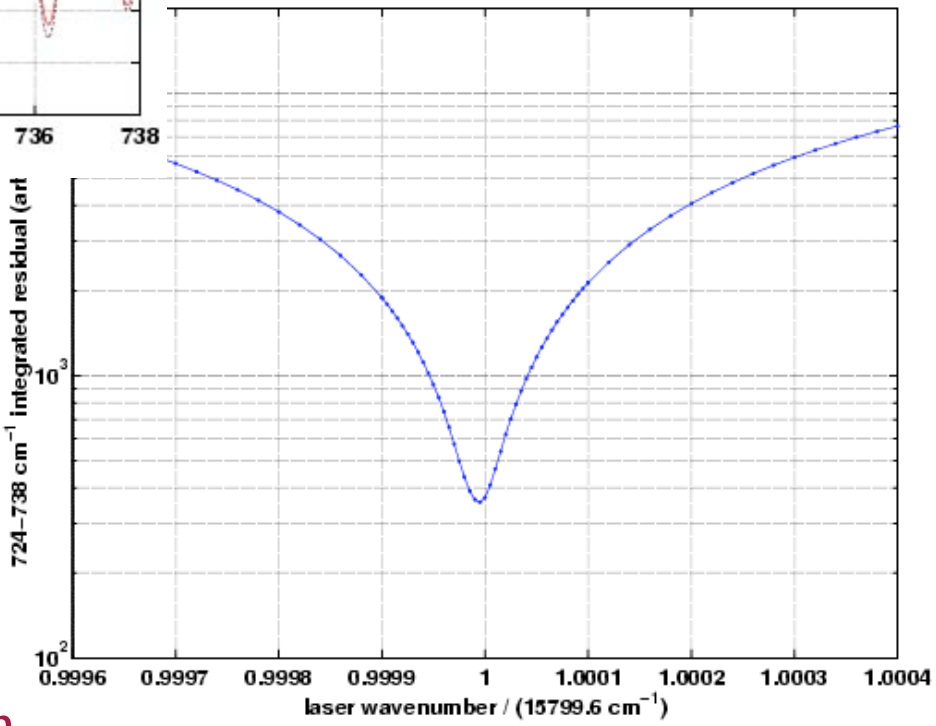
Below cloud (ground based AERI-ER from 22:35 to 23:00)

Atmospheric Spectral Calibration: S-HIS



Atmospheric CO_2 lines

AIRS does similar atmospheric spectral calibration



Wavenumber Scale chosen to minimize difference

Estimated accuracy =1.2 ppm (1 sigma)

With many samples, the 3-sigma accuracy is < 1 ppm